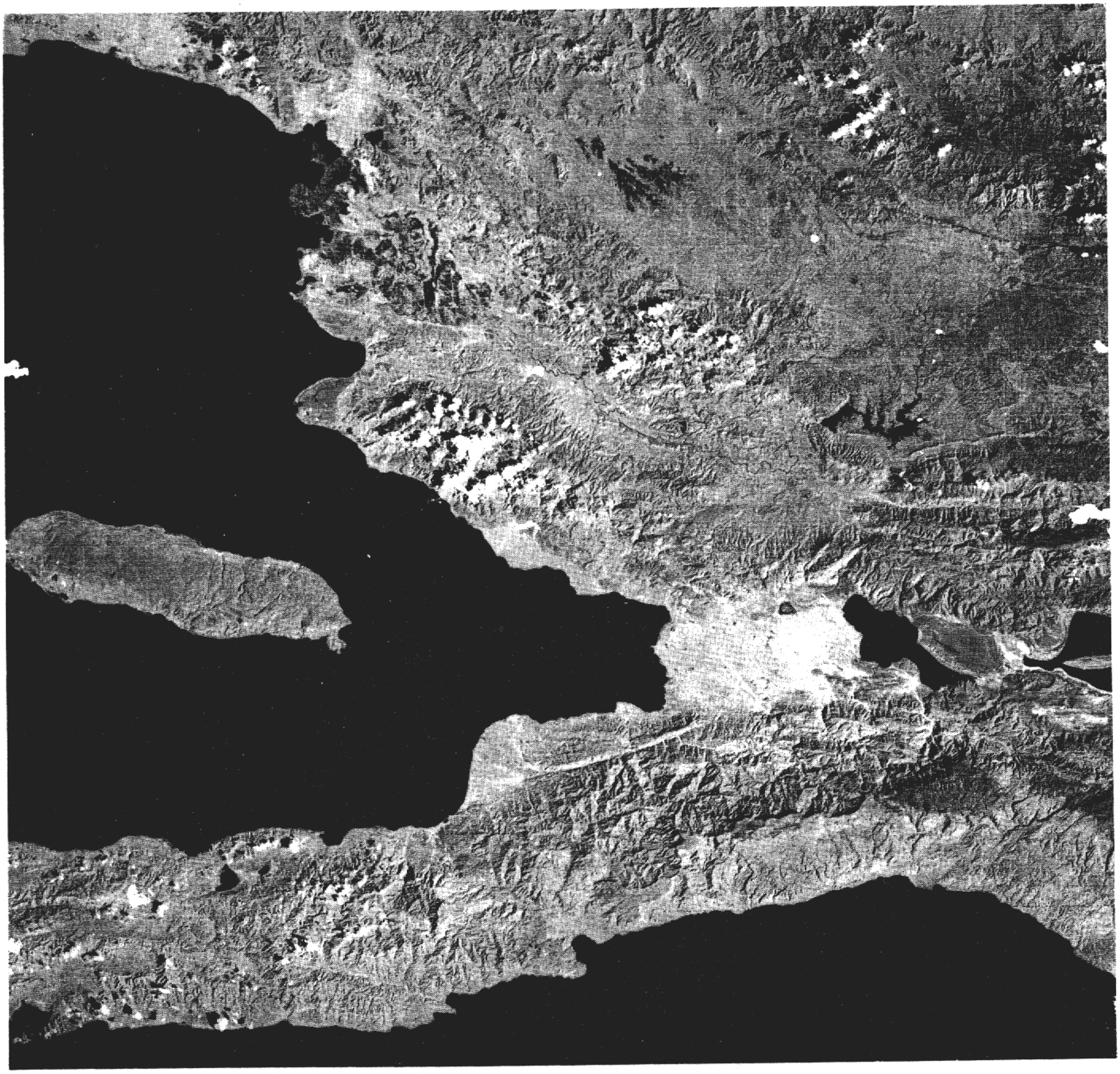
SURVEY OF THE GEOLOGY of HAITI

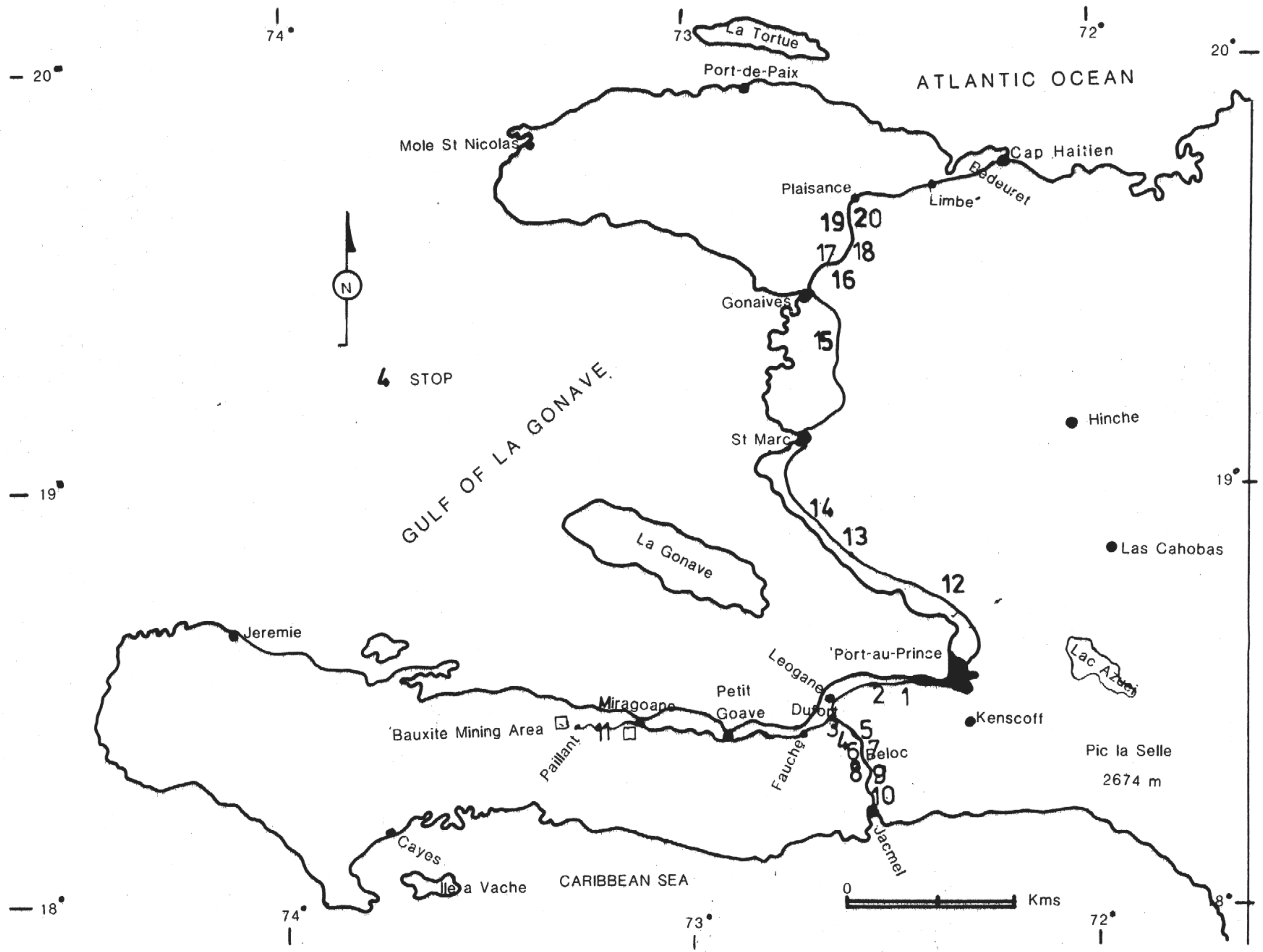
GUIDE TO THE FIELD EXCURSIONS IN HAITI

MARCH 3 - 8, 1982



by Florentin J-M. R. Maurrasse

MIAMI GEOLOGICAL SOCIETY



ATLANTIC OCEAN
La Tortue
Port-de-Paix
Mole St Nicolas
Cap Haitien
Plaisance
Limbe
Bedeuret
19 20
17 18
16
Gonaives
15
4 STOP
GULF OF LA GONAVE
Hinche
St Marc
14
13
Las Cahobas
La Gonave
12
Jeremie
Port-au-Prince
Lac Azuei
Leogane
2 1
Petit Goave
Miragoane
Dufort
Kenscoff
Bauxite Mining Area
11
3 4 5 6 7
Beloc
Pic la Selle
2674 m
Paillant
Fauche
8 9
10
Cayes
Jacmel
Ile a Vache
CARIBBEAN SEA
0
Kms
74°
73°
72°
20°
19°
18°

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OF THE

MIAMI GEOLOGICAL SOCIETY

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By

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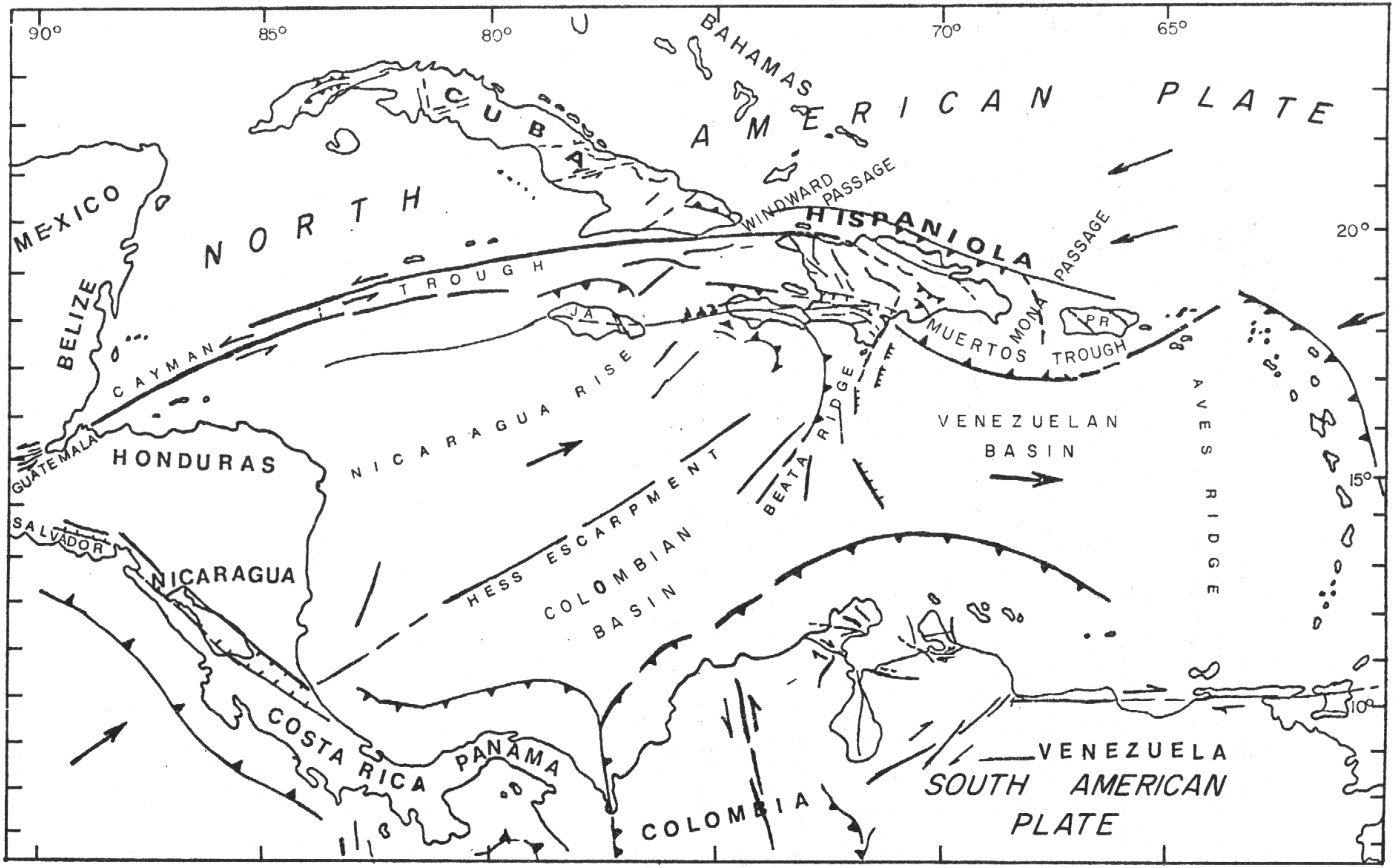

FIGURE 1 - General structural setting and main directions of crustal motion in the Caribbean region (Adapted from various authors and modified after Maurrasse, 1982 c)

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FOREWORD

The purpose of this field guide is to provide a general view of the geology of the Republic of Haiti, including some aspects of the geology of the island of Hispaniola as a whole. It is by no means an exhaustive look at the geology of the area. Nonetheless, the transects cover enough of the main geologic features of Haiti to allow a good appreciation of its geology and its relation to the remainder of the island as a whole. I will also discuss some of the new data available on the areas covered, and their implications concerning the geologic history of Hispaniola.

SYNOPSIS OF THE GEOLOGY OF HAITI

INTRODUCTION

The island of hispaniola is the second largest of the Greater Antilles after Cuba. It lies between parallels 17°39′ and 20° north latitude and meridians 68°20′ and 74°30′ west (Figure 1). The Atlantic Ocean lies at its northern side while the Caribbean Sea is at its southern side. It is separated from Cuba by the Windward Passage, and from Puerto Rico by the Mona Passage. A submerged ridge complex extends from the Southern Peninsula of the Republic of Haiti westward toward Jamaica, whereas another prominent ridge complex (The Beata Ridge) extends southward from the Barahona Peninsula in the Dominican Republic. The latter ridge complex actually subdivides the main part of the Caribbean Sea into two major basins: The Venezuela Basin to the east and the Colombia Basin to the west (Figure 1).

The island of Hispaniola as a whole is extremely mountainous. It includes the highest elevation of the Caribbean islands at Peak Duarte, which culminates at 3087 meters in Central Dominican Republic (Figures 2, 3). History reports that when Christopher Columbis, upon returning from his first discovery trip to the New World, wanted to describe Hispaniola, he crumbled a piece of paper which he said may best explain the geography of the island. Columbus graphic representation cannot be more correct indeed. The earlier inhabitants of the island, the now extinct Arawaks, in fact called it "Haiti" which meant mountainous land in their language. Thus the name Haiti adopted for the western side of the island is an original Arawak name. The island was also known by the Arawaks as Bohio (land with numerous villages) or Quisqueya (large land). The name Hispaniola (Espanola) was given by Columbus to mean

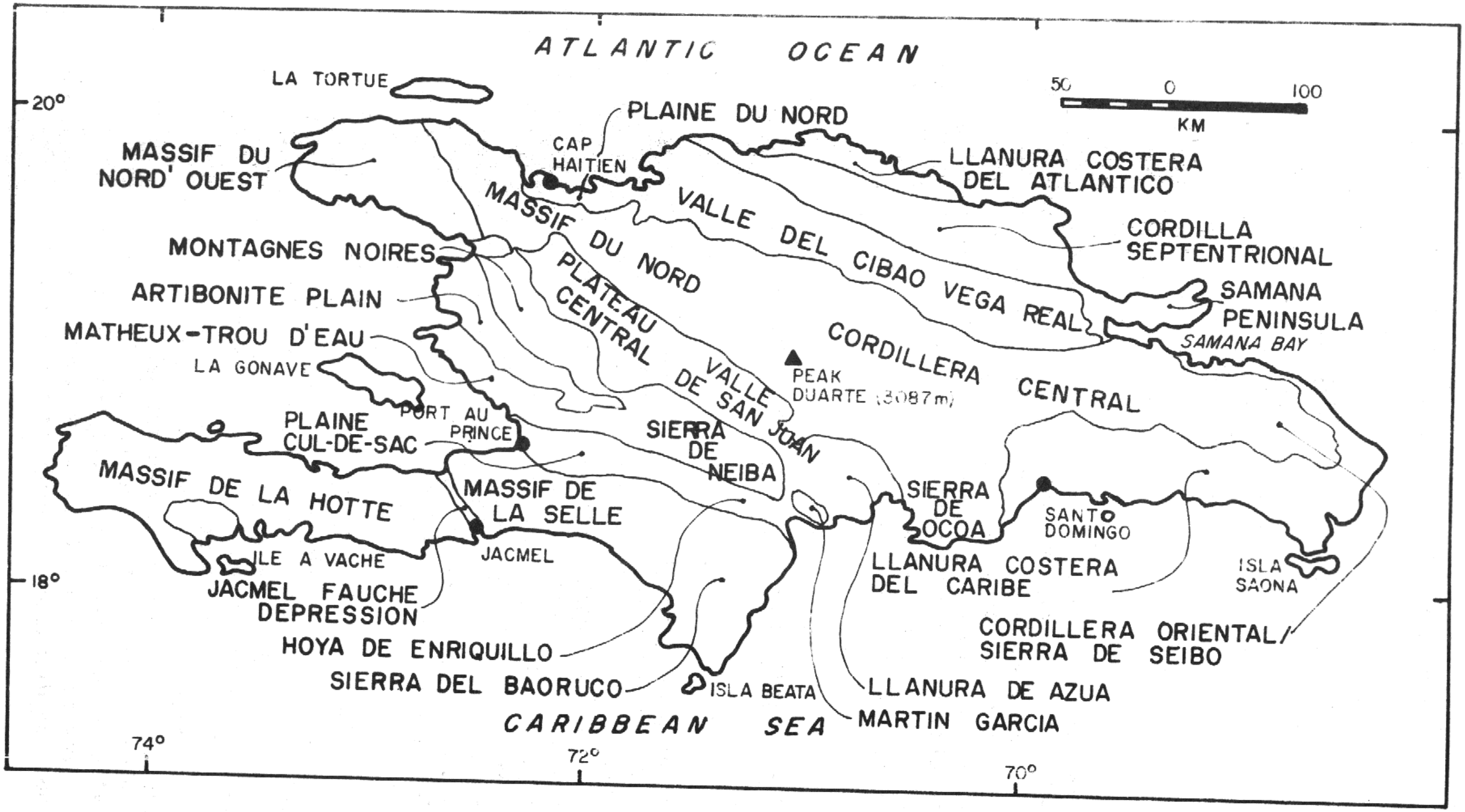


FIGURE 2 : General Physiographic Provinces of Hispaniola.

4

"little Spain". It should also be remembered that when the first Spanish settlers reached the island in 1942 a rich and peaceful Arawak civilization was flourishing there. The island was divided into five Kingdoms called "Caciquats": The Marien in the Northwest, the Magua in the Northeast, the Maguana in the Central regions, the Higue in the Southeast, and the Xaragua in the Southern Peninsula.

After a rather tumultuous colonial history, punctuated by heroic revolutions, two nations of Afro-European stocks emerged from the island where the Arawaks were virtually exterminated. The Republic of Haiti became independent in 1804, and the Dominican Republic in 1844.

The Republic of Haiti occupies approximately the western third of the island (28,700 km^2), and the Dominican Republic the eastern two thirds (48,500 km^2).

GENERAL PHYSIOGRAPHIC SETTING OF THE ISLAND OF HISPANIOLA

Geomorphologically the islands can be divided into two major portions separated by the prominent Cul-de-Sac/Enriquillo depression (Figure 2, 3). Relief north of this depression exhibit a prevailing northwest- Southeast trend, whereas those south of the depression exhibit a prevailing east-west orientation swinging to a northwest-southeast trend in the Barahona region (Figure 2).

On the whole ten main physiographic units can be recognized from North to South:

> The northermost physiographic unit consists of a quasi rectilinear mountain range about 200 kilometers long, along the north coast of the Dominican Republic. It is referred to as the Cordillera Septentrional or Monte Cristi Mountains. The Llanura Costera del Atlantico and the Samana Peninsula can be added to this physiographic unit, although the latter is separated from the Cordillera by a marked depression called the Gran Estero, which was a seaway in recent geologic times.
>
> This physiographic unit is bounded to the north by the Camu fault system (Figure 3), to the South by the most conspicuous Magua fault whose sharp escarpment gives rise to sudden relief changes toward the Cibao Valley to the South (Figures 2, 3). The maximum elevation of this unit is 1249 meters, reached at Peak Diego de Campo northwest of the city of Santiago. The eastern portion shows smoother relief, and the transition is rather progressive toward the valley which is often called Vega Real in the area (Figure 2).
>
> The island of La Tortue (Figures 2,3) may also be considered as part of this physiographic unit. It lies off the north coast of Haiti from which it is separated by an 8.9 to 15 Kms wide and 1400 meter-deep structural strait, called the "Canal de la Tortue" or La Tortue Channel. The island is 37.5 Kms long and is about 7 Kilometers wide, its maximum elevation is of 340 meters at Morne La Visite. Most of the

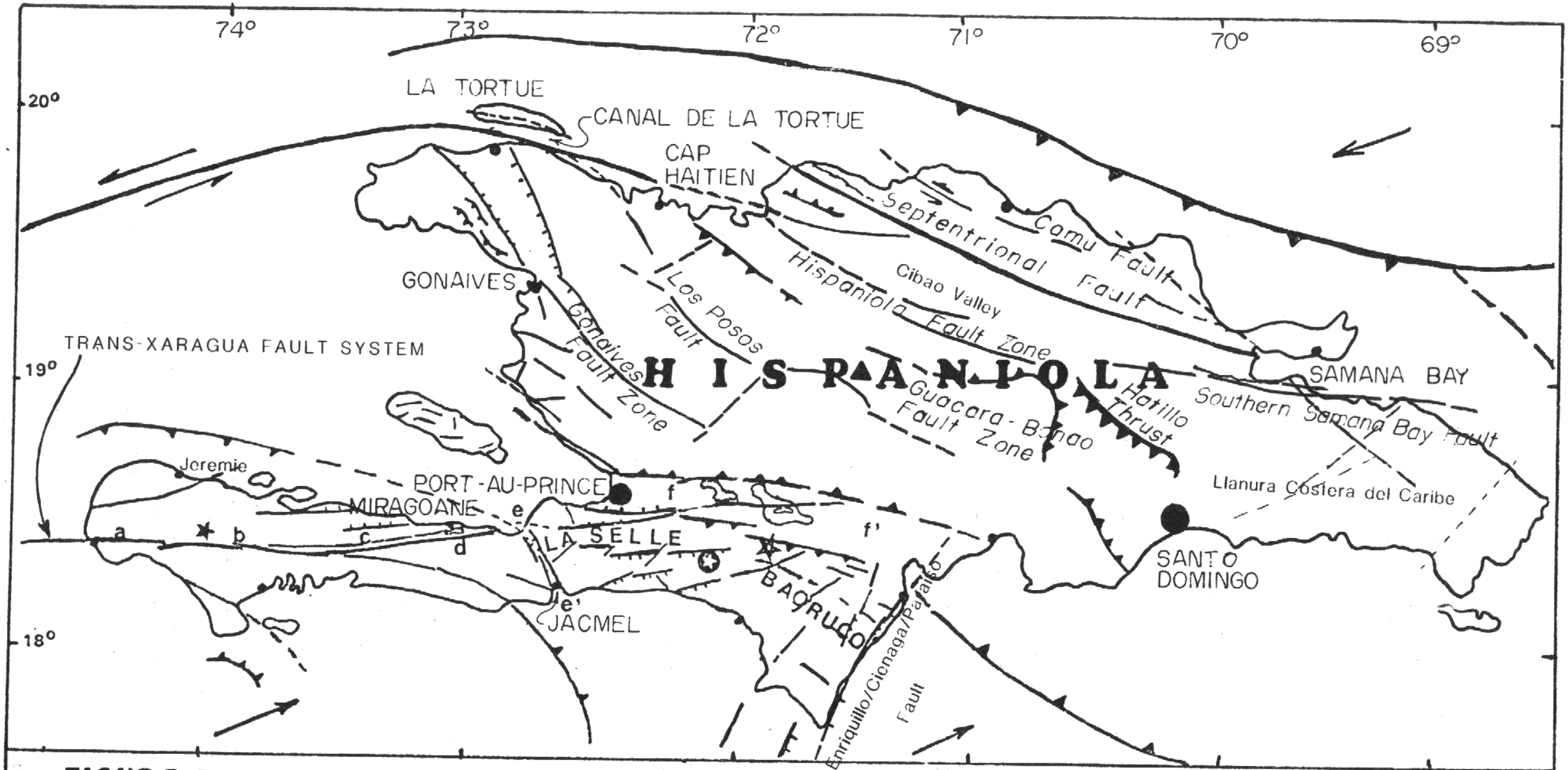


FIGURE 3 - General structural setting of Hispaniola.

Normal faults
Thrust faults
Unspecified faults
▲ Peak Duarte : 3087 m
★ Peak Macaya : 2347 m
✪ Peak de la Selle : 2674 m
☆ Loma del Toro : 2367 m

Localized direction of strike-slip motion
Main direction of crustal displacement

a) Rivière des Anglais et de Tiburon; b) Vallée de l'Asile; c) Vallée de Fond des Nègres; d) Etang de Miragoane; e-e') Jacmel-Fauché dépression; f-f') Cul-de-Sac - Enriquillo Graben.

(Modified after Maurrasse et al., 1982 ;Lewis,1980) land lies between 240 and 300 meters with a characteristic northward dipping plateau showing extensive Karst features. The plateau consists of successive terraces which are of Pleistocene age. Two of these elevated reef terraces are particularly conspicuous as they form sharp escarpments. Metamorphic rocks are present under the coral cap, and in the south facing escarpment of the island.

The second physiographic unit of Hispaniola consists of a structural low-land immediately south of the Cordillera Septentrional. It is bounded to the South by the foothills of the Cordillera Central (Figure 2). The northwestern end of the depression is called Plaine du Nord in Haiti, and the Cibao Valley in the Dominican Republic. The extreme southeastern end is also known as Vega Real in the Yuna River area adjacent to Samana Bay (Figure 2). This depression is about 290 Kilometers long and varies in width from about 5 to 40 Kilometers. Two major rivers, the Yaque del Norte and the Yuna flow respectively northwest (to the Atlantic) and Southeast (into Samana Bay) within the Cibao Valley. Both rivers show signs of recent rejuvenation as they are now flowing at levels 15 to 30 meters below the main level of the depression. The southwestern portion of the Cibao Valley south of the Yaque del Norte and northwest of Santiago includes a smooth, hilly topography about 200 meters high dissected in Neogene marine deposits. These series are composed of polygenic conglomerates sandstones, marls, sandy clays and coralliferous limestones that unconformably overlie older metamorphic rocks. These neogene deposits have been known as Cercado Formation (Maury, 1919 p. 591), Gurabo Formation (Cooke, 1920) and Mao Formation (Vaughan et al. 1921, p.80), from older to younger respectively.

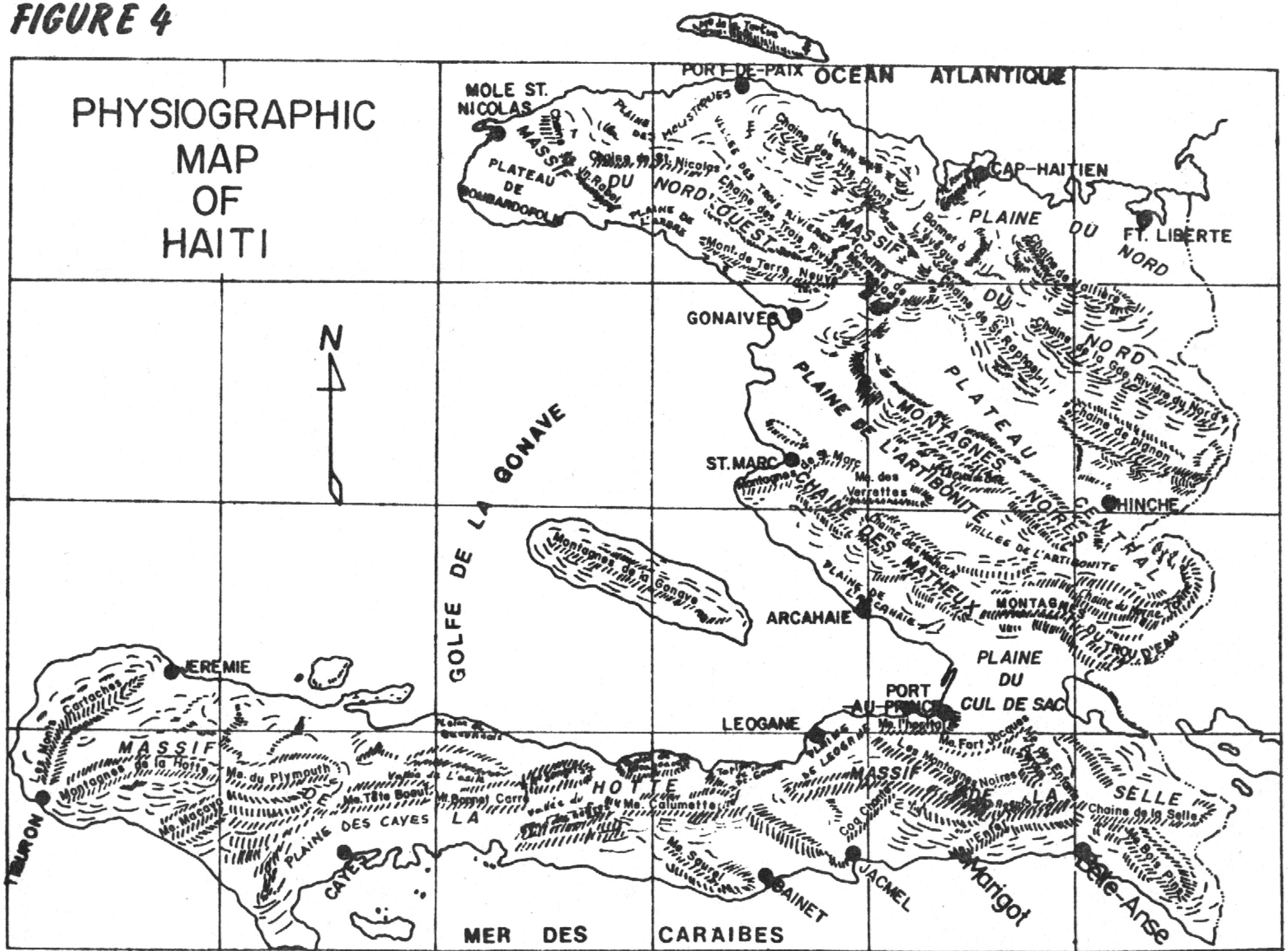
The third physiographic unit of Hispaniola includes the most important mountain system of the island. It constitutes the backbone of the portion of Hispaniola north of the Cul-de-Sac/Enriquillo depression. The northwestern regions/ are called Massif du Nord in Haiti, and the remaining southeastern regions form the Cordillera Central in the Dominican Republic (Figure 2). This mountain system is the most impressive of the whole island and of all the antilles as well. It comprises the tallest elevation (Peak Duarte 3087 meters) of all the Caribbean islands. The width of the third physiographic unit varies from less than 25 Kilometers to more than 90 Kilometers toward the southeast where it bifurcates south. The southern branch is known as the Sierra de Ocoa, whereas the easternmost branch is known as Sierra de Seibo or Cordillera Oriental (Figure 2). This physiographic unit is also characterized by sharp relief dissected by the river's drainage systems. In addition, the southeastern areas adjacent to the Vega Real exhibit extensive karst features which have developed over a small 200 meter-high plateau of biocalcirudite. These areas are known as Los Haitises, from the original Arawak word as previously mentioned. The central mountain range plays a very important hydrologic role on the island as its four major rivers: Artibonite, Yaque del Norte, Yaque del Sur, and Yuna, have their headwaters on its slopes.

Two prominent fault zones, the Hispaniola and Bonao Faults, form important topographic features in the central and eastern Cordillera. The Bonao Fault forms a prominent escarpment southwest of Bonao where it has a marked and continuous curvature, and separates the highly elevated mountains of the Cordillera from the Bonao Valley (Lewis, 1980).
The southern boundary of this physiographic unit is somewhat diffuse, as it grades into the Plateau Central/ Valle de San Juan and Llanura de Azua physiographic unit (figure 2). The western boundary may be taken as the los Posos San Juan Fault (Figure 3), whereas an apparent fault to the east is not yet defined. (Lewis, 1980)

The Central Cordillera system includes the oldest rocks on the island. They vary from metasediments to igneous intrusives (tonalites, gabbros), and extrusives believed to be of at least Early Cretaceous age (Bowin, 1966; Kesler et al., 1977). Ultramafics such as serpentinized peridotites are also known within this area. Although most of the Central cordilleran system is composed of metamorphic and igneous rocks, the northwest Hispaniola Fault zone forms a graben which contains Oligocene clastic deposits (Lewis, 1980). Tertiary sediments also occur at the southern end of the Sierra de Ocoa, and in the Cordillera Septemtrional, region of los Haitises.

To this physiographic unit can also be attached the Llanura Costera del Caribe (Figure 2), which is underlain by rocks of the Cordillera. Eight of these terraces can be recognized between Punta Palanque and la Romana, and may reach height of 80 meter or more above present sea level (Schubert, 1980). They gradually blend with the foothills of the Cordillera Central. The relative height of the terraces from each other end of this physiographic province clearly indicates the difference in uplift rate between the northwestern and southeastern parts of the island, as suggested by Horsfield (1977). In fact, while the first three lowest terraces in this area occur at 3 - 6 meters, 8 - 9 meters and 16 - 17 meters respectively (Schubert, 1980), in the Northwestern Peninsula of Haiti similar prominent terraces occur at 16± 3 meters, 28± 3 meters and 52 meters respectively (Dodge et al., 1983). Furthermore, radiometric dating of these terraces also shows significant differences between the two areas. The lowest terraces along the southeastern coast of the Dominican Republic yielded a Th-230/U-234 date of 121,000 ± 9000 to 155,000 ± 13,000 years (Schubert, 1980). Similar dating of the terraces along the coast of the Northwestern Peninsula of Haiti produced average ages of 130,000, 108,000 and 81,000 years B.P. from the hightest to the lowest terrace respectively (Dodge et al., 1983). It is thus evident that the lowest terrace (3-6 meters) in the Llanura costera (figure 2) corresponds approximately to the third (52 meters) terrace near Mole Saint Nicolas, a difference of about 46 meters. Considering that when the lowest terrace of the southeastern regions was being formed (about 125,000 years B.P.) sea level was 6 meters higher than it is today, it is clear that uplift there has been partically negligible. Rapid uplift of one region while another one stays stationary is possible in Hispaniola because of extensive dislocation caused by major fault zones. The Pleistocene case is an illustration of the main tectonic history of the whole island throughout time, as I will point out further during the transects.

FIGURE 4



(Adapted from Maurrasse, editor, 1982)

The fourth important physiographic unit of the island consists of the low-land called Plateau Central in Haiti and Valle de San Juan and Llanura de Azua in the Dominican Republic (figure 2). The altitudes in this unit vary from sea level to 400 meters in the Valle de San Juan, and to slightly more (405 meters) in the center area of Plateau Central at the structural dome of Potosuel, north of Maissade (Figure 4). This whole physiographic unit shows extensive youthful drainage systems, which are particularly conspicuous in the Plateau Central. The southern boundary of this unit is defined by high relief formed by the Montagnes Noires and the Sierra de Neiba (figure 2). High-angle south dipping reverse faults are also associated with the southern boundary of this physiographic unit where sediments at the edges of the low-land show nearly vertical to slightly overturned structures.

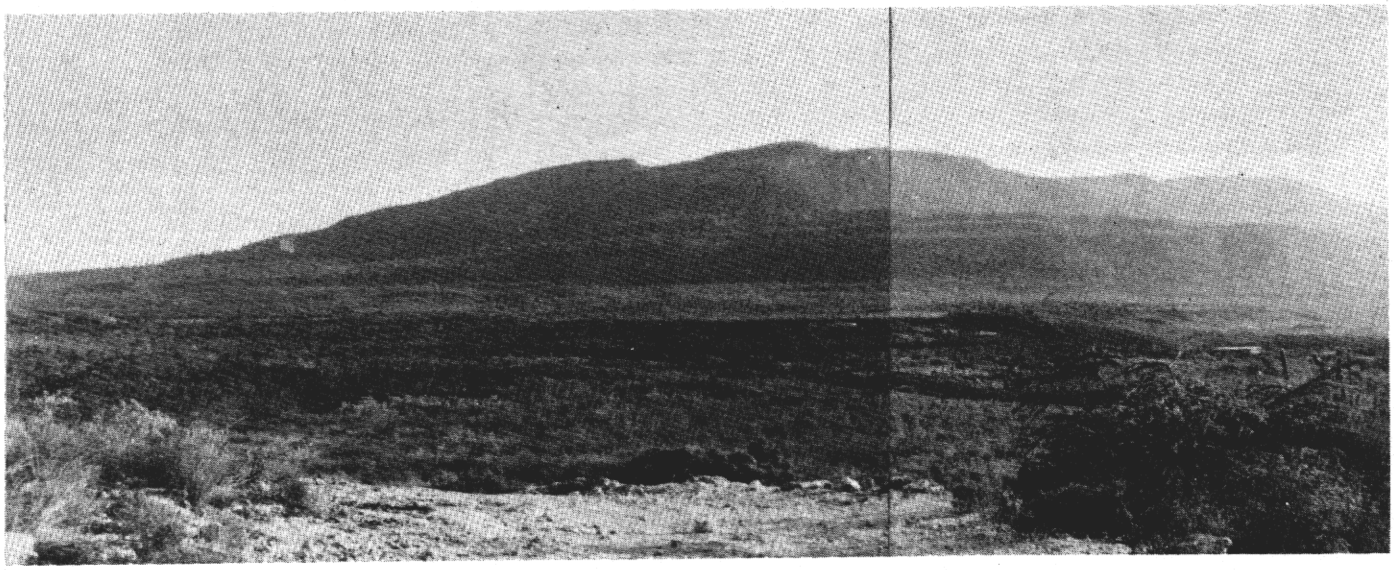
Sediments of Tertiary age filled these basins in which they may reach thicknesses greater than 5000 meters (Rigaud and Pierre-Louis, 1982).

The fifth physiographic unit of Hispaniola has a broad S-shape and includes three main subdivisions separated by major fault scarps and depressions. It includes the Massif du Nord'Ouest and Montagnes Noires in Haiti, and the Sierra de Neiba in the Dominican Republic (figure 2). The southeastern end of the Sierra de Neiba, namely the Sierra de Martin Garcia, is separated from the main mountain chain by a depression in which flows the Rio Yaque del Sur.

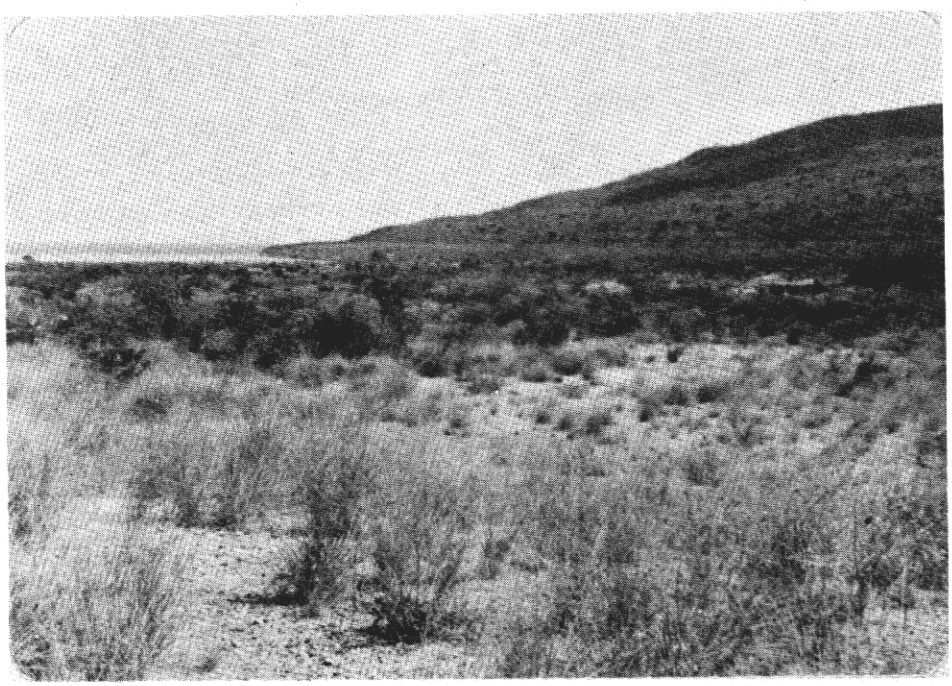
The northwestern Peninsula is separated from the Massif du Nord of the Central cordilleran system by a major structural depression associated with vertical faulting, the Gros Morne graben in which flows the Trois Rivières. The western end of the Northwestern Peninsula is characterized by extremely well developed raised reef terraces, (figure 5) which are also the best preserved Pleistocene terraces known in the Caribbean region. Their analogs can be found across the Windward Passage in southern Cuba, particularly at Point Masi (del Busto Alvarez, 1975). The top of the coralline limestone cap forms the Bombardopolis Plateau at a maximum elevation of approximately 600 meters. Oligocene pelagic limestones and volcanics, and Miocene hemipelagic marls to sandy marls underlie the coral rock. The southeastern portion of the Northwestern Peninsula consists of the Massif de Terre Neuve. It is a very steep and rugged relief with a maximum elevation of 1100 meters at Morne Goreille. This mountain range is also made up of limestones, igneous intrusives and extrusives (andesites, diorites) of Cretaceous and Tertiary ages. The Terre Neuve mountains include an extensive zone of porphyry copper mineralisation.

The Montagnes Noires range is separated from the Northwestern Peninsula by the Gonaives Plain, and continues southeastward into the Sierra de Neiba. The Maximum elevation in these mountains is reached at Peak Neiba, 2,279 meters. Their total length is about 120 kilometers, and their width varies between 3 and 20 kilometers. A major fault system, the Gonaives Fault Zone, limits the western and southwestern boundaries of the Montagnes Noires with the Artibonite Valley (figure 3). The Montagnes Noires and the Sierra de Neiba both contain Teriary limestones and volcanics.

FIGURE 5



a : Pleistocene reef terraces along the northern coast of the Northwestern Peninsula of Haiti, region of Mole Saint Nicolas.



b: Pleistocene reef terraces near Baie de Henne, southern side of the Northwestern Peninsula of Haiti.

The tenth physiographic unit of Hispaniola lies west of the Jacmel-Fauché depression. It is referred to broadly as the Massif de la Hotte (Figures 2,4). This unit is physiographically more complex than suggests the single name attached to it. In fact two distinct orographic sub-zones can be recognized north and south of the Trans-Xaragua fault which transects the area diagonally (Figure 3). This fault system includes from east to west, the low-land area of the Etang de Miragoâne, the Vallée de Fond des Nègres, Vallée de l'Azile, and the valley of Rivière des Anglais and Riviere de Tiburon.

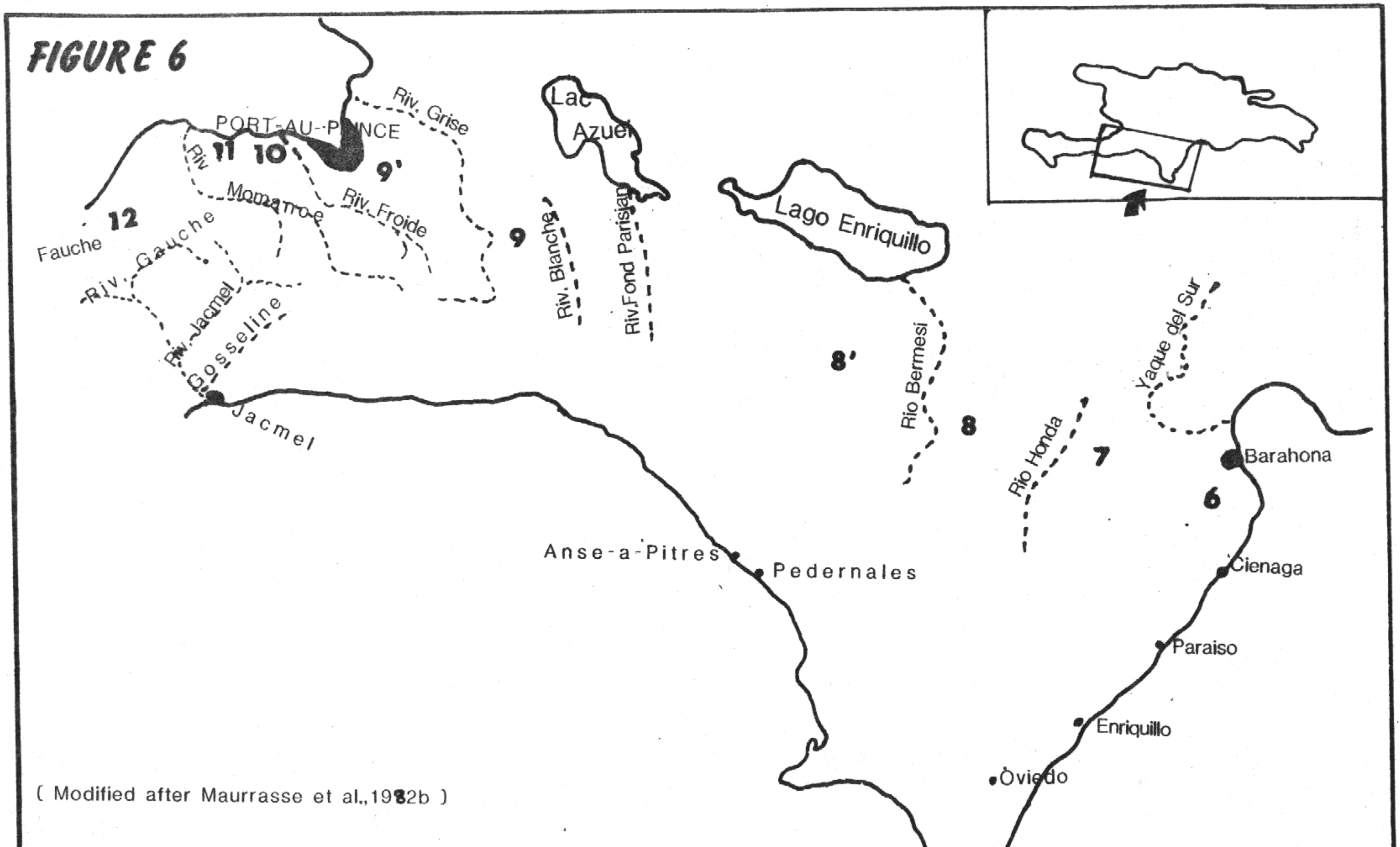
North of the fault system, and in a similar direction, the mountains of Bonnet Carré, Plateau de Rochelois and Macaya Massif form a series of reliefs controlled by secondary fault systems. The highest elevation of the La Hotte Physiographic unit, Peak Macaya (2347 meters) is one of these uplifted blocks bounded by multidirectional or orthogonal fault systems. The Monts Cartaches at the extreme northwest end of the Peninsula is also a fault-controlled subunit, (Figures 3,4).

South of the Trans-Xaragua fault, other fault-controlled reliefs form the remainder of the La Hotte physiographic unit. They include Morne Saurel and Fond des Negres. Geologically the La Hotte physiographic unit is more complex than its eastern counterpart in the Southern Penninsula. It is more intensely deformed and its Lithofacies more diversified than those found in the La Selle-Baoruco block. Its basement is composed of intensely deformed rocks of the Dumisseau formation. In certain areas extreme multiphase deformations led to extreme dislocation of originally continuous lithologic unit giving rise to a tectonic melange, as can be seen on the road Carrefour Dufort - Jacmel (Figure 9).

GENERAL STRUCTURAL SETTING

Given its medial position relative to the major structural features of the Caribbean (Figures 1, 10), the island of Hispaniola may be considered the structural hub of the region. As can be seen in figure 1, Hispaniola lies at the intersection of the main tectonic features of the present Caribbean plate, and most of its major structures can be related to wrench-fault tectonism between the eastward moving Caribbean plate and the westward moving North American plate. Added complexity developed because of differential motions between the sub-blocks, and also changes in stress field during differential rotations between the major adjacent continental plates (Ladd, 1976). Consequently, a complex orthogonal fabric of dislocation has developed throughout the island, and in the adjacent Caribbean Sea as well (Case and Holcombe, 1980). Most of the major fault systems indicated earlier have been activated several times and diachronically, the latest cycle of activity was Late Pleistocene (Maurrasse, 1982). These fault systems have apparently played a major, if not the most important role, in the distribution of sedimentary environments throughout the geologic evolution of Hispaniola. Their differential motions through time led to the development of series of troughs and banks, sometimes individual islands. These early features heralded the present structural setting of the island, as defined by the major physiographic units discussed herein above.

FIGURE 6



(Modified after Maurrasse et al., 1982b)

Sketch map of the major rivers in the LA SELLE-BAORUCO block.
Numbers refer to location of stratigraphic sections shown in figures 19 and 20

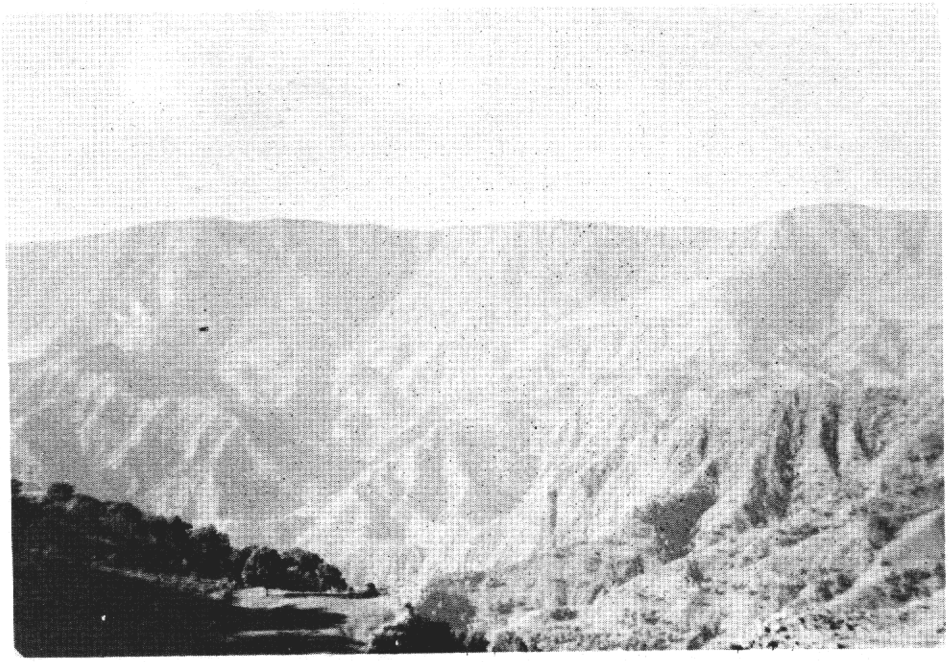
1920). Most of the clastic supplies appear to have derived from alluviums carried by Riviere Grise and the Rio Yaque del Sur at least throughout the Neogene (Maurrasse et al., 1980 b; 1982b). Other smaller rivers shown in figure 6 have also played limited roles in providing clastic sediments to the basin. The youngest rocks exposed in this physiographic unit consist of pleistocene coral reefs, which are exceptionally well preserved and occur along the edges of the central region.

Late Pleistocene compressions caused considerable deformation along the edges of the depression where there is limited thrust faulting, and significant uplift.

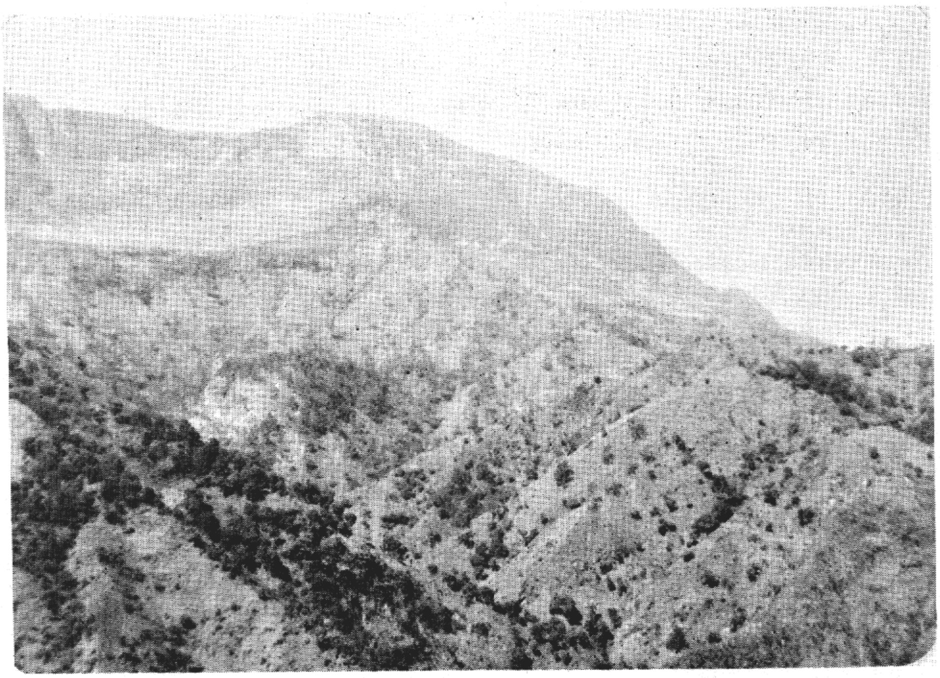
As pointed out earlier, the southern part of the island south of the Cul-de-Sac/Enriquillo graben is very distinct from the northern areas in their overall structural trend. The southern part can be further subdivided into two major physiographic units separated by the Jacmel/Fauche depression (figures 2,3).

The ninth physiographic unit of Hispaniola consists of the mountains east of the Jacmel/Fauche depression. They are known as the Massif de la Selle in Haiti, and the Sierra de Baoruco in the Dominican Republic. They form a unit recently described as the La Selle-Baoruco block (Maurrasse et al. 1980, 1982b) in which the geologic setting is much reminiscent of the adjacent Beata Ridge (figure 1). This mountain range shows extremely constasting reliefs as the areas of limestone terranes exhibit extensive Karst features whereas the igneous terranes develop smoother, but much steeper, reliefs. Dip-slopes along the flanks may be greater than 60° angle (figure 7). The highest summits of the Southern Peninsula, namely the Peak La Selle (2674 meters) and Peak Loma del Toro (2367 meters) occur in this unit (Figure 3). The river valleys (Figures 6,8) in this region are mostly controlled by major and minor fault systems which transct the mountains. The most spectacular fault scarps of the islands are found in this physiographic unit where the most remarkable faults are those related to the Momance-Riviere Froide Fault (figure 8), the La-Selle Fault (Figure 8) and the Cienaga-Paraiso-Enriquillo Fault (Figure 3), respectively. Most of the topography of the La Selle-Baoruco block appears to be controlled by high-angle, partially tilted faults which gave rise to complex step-like plateaus with sharp drop-off edges asymmetrically distributed on either side of the main axis. These structural plateaus are best developed south of the axial region where the topography displays a series of spectacular steps which lead practically down to the adjacent Venezuela Basin in a sharp drop off (Maurrasse et al., 1979a), much in the same manner described by Roemer et al. 1976 for the northern portion of the Beata Ridge. A complex of igneous and sedimentary rocks (The Dumisseau Formation, Maurrasse et al., 1979a) constitutes the basement rocks which are overlain by limestones of various lithofacies. Many rock formations have been described from this area (cf. subsequent paragraphs in this field guide). Faster weathering of the igneous rocks in the central region of the Massif de la Selle has developed a relief reversal in the igneous rocks, which presumably stood higher than the limestone areas.

FIGURE 7



a: View looking south at the La Selle Escarpment. High cliff is of Eocene limestones - Sharp crested ridges below are igeous rocks of the Dumisseau Fm.



b: View looking south-southwest at the La Selle Escarpment. Mount Cabaio shows denuded fault scarp in center of picture.

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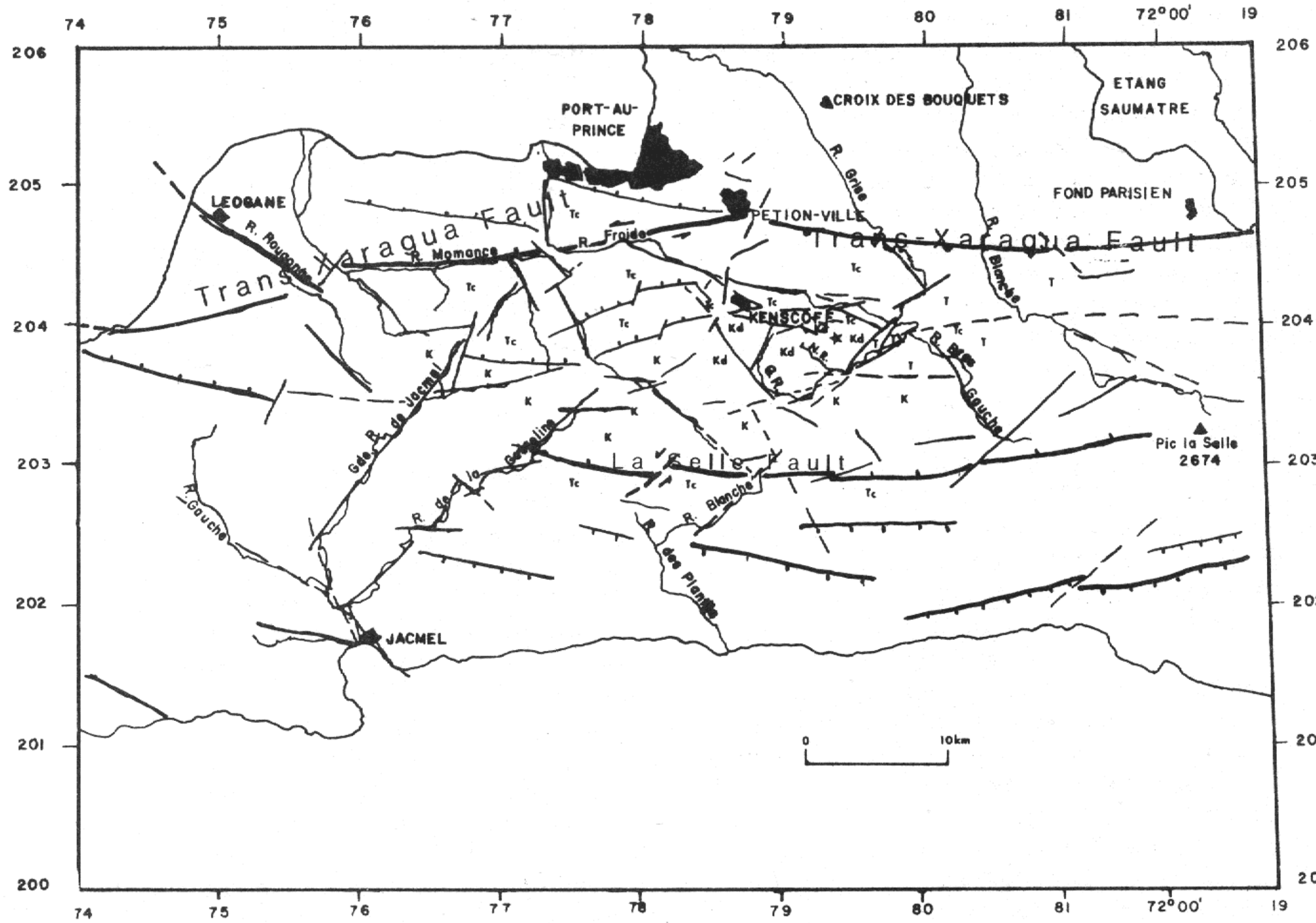
FIGURE 8



(From Maurrasse et al., 1979).

a: Simplified structural map of the eastern portion of the Southern Peninsula of Haiti. GR = Grande Riviere; RN = Riviere Nan Roseau; T = undifferentiated Tertiary (Miocene) rocks; Tc = Eocene limestones; K = Cretaceous: igneous and sedimentary complex of the lower member type; K_D = Cretaceous: igneous and sedimentary complex of the St. Dominique Member; ★ shows Dumisseau.

b: Sedimentary layers intercalated with basalts, Dumisseau Fm.

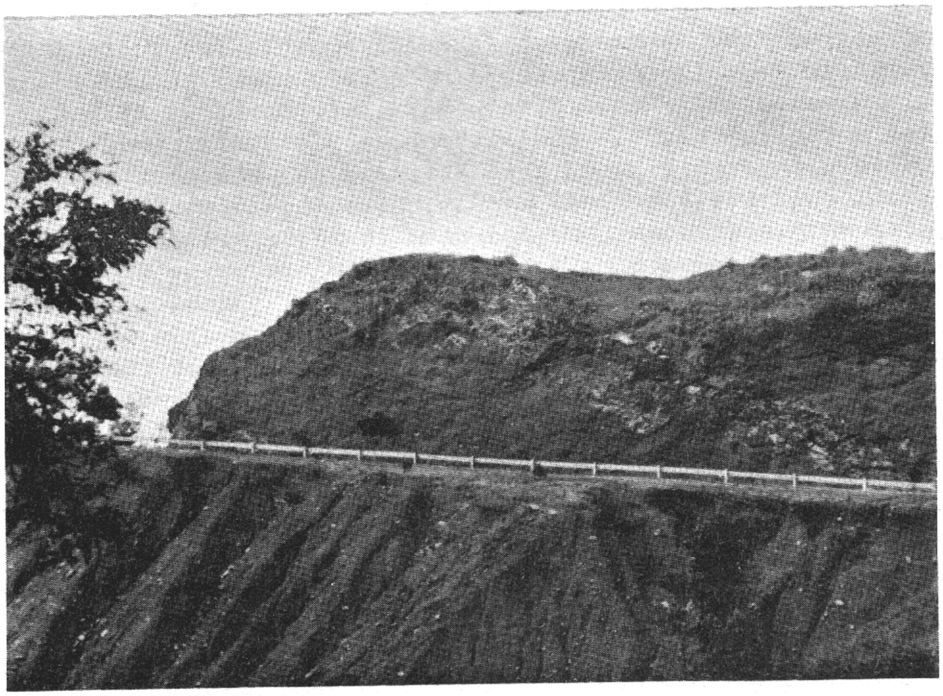
As can be seen from Figures 1, 10, Hispaniola is bounded and transected by major fault systems related to major structural dislocation along the northern edge of the Caribbean plate. These major fault zones also coincide with intense source of seimic activities on the island (Scherer 1912; Sykes and Ewing 1965; Molnar and Sykes 1969; and others). Nonetheless, an intense source of intermediate earthquake foci has also been reported beneath the eastern end of Hispaniola (Sykes and Ewing, 1965), although there is no known surface dislocation in the area. The hypocenters further show an apparent increase in depth dipping beneath the island. Bracey and Vogt (1970) suggested that such distribution pattern of the earthquake foci represent an actual underthrusting zone toward the southeast. They also indicated that the unnderthrusting plane could vary in dip from about 11^{o} in the northeast to 60^{o} in the southeast areas. The small underthrusting slab would have a hinge fault at its southeastern and northwestern ends, which would mark the juncture of the Puerto Rico and Cayman fault systems (Bracey and Vogt, 1970). Molnar and Sykes (1971) objected to this interpretation on the basis that there are no historically active volcanoes in eastern Hispaniola. Furthermore, they pointed out the fact that the seismic pattern scatters considerably over Hispaniola, and west to Jamaica. Thus, deformation inducive to seismic activities on the island is probably taking place over a broad fault zone or fault system, and a simple plate boundary between the Cayman Trough and the Puerto Rico Trench would not appear to exist (Molnar and Sykes, 1971). This view is compatible with the actual complexity of the fault systems of the island (figure 3), as previously mentioned. Nonetheless, Frankel (1982) reported that a composite focal mechanism for microearthquakes along the northeastern border of the Caribbean plate indicates that oblique underthrusting of the North American plate beneath the Caribbean plate occurs in the area farther east of Hispaniola. The oblique motion is accomodated along a thrust plane that dips at a relatively shallow angle beneath the Virgin Islands platform.

GEOLOGY

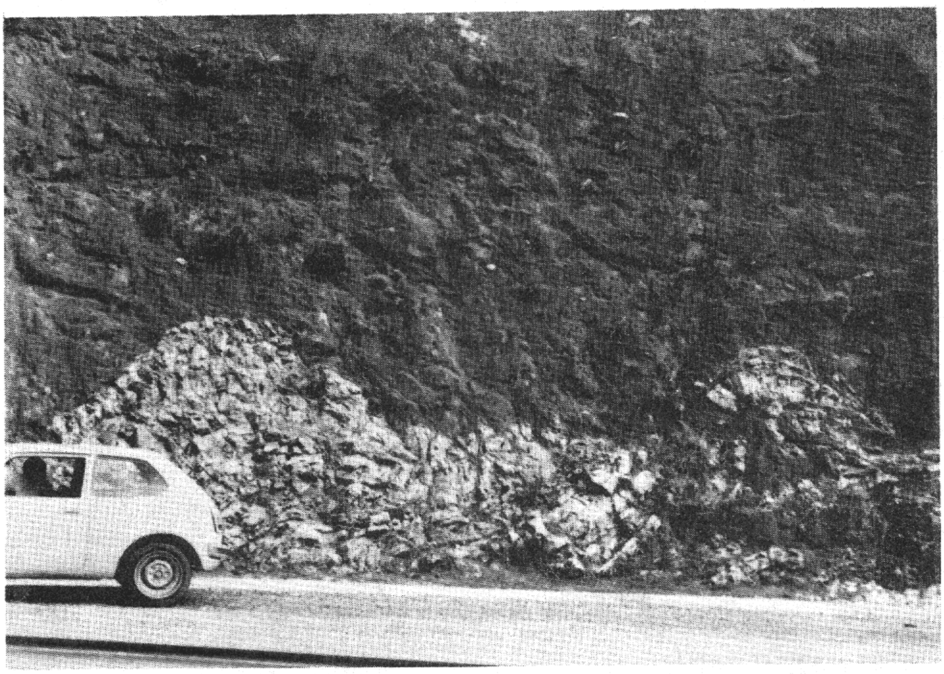
Taking account of the wealth of information that has become available on the geology of Hispaniola during the past ten years or so, it has also become clear that a revision of the geological history of the island is wanting. Nonetheless, it should be recognized that early works such as those by Tippenhauer, 1899, 1909; Jones, 1918; Vaughan et al., 1921; Woodring et al., 1924; Butterlin, 1954, have served worthy purpose and deserve commendation.

Recent summaries synthesizing the geologic history of the island based on most data gathered in the sixties and seventies have been given by Bowin (1975), and Lewis (1980). A model suggesting a possible scenario for the evolution of Hispaniola and the Caribbean as a whole has also been discussed by Maurrasse (1982c). In the present guide the writer will not attempt to reconstruct the detailed geologic history of the island, but will instead discuss some aspects of the paleogeography and tectonic of the island as can be deduced from the geologic record examined during the field trip.

FIGURE 9



a: Dumisseau Formation as seen in road cut on the road between Carrefour Dufort and Jacmel.



b: Dislocated limestone block in the igneous complex of Dumisseau Formation. Same location as above .

STRATIGRAPHY

Geologic information available to date on Hispaniola gives little evidence to suggest the presence of rocks older than lower Cretaceous or possibly Jurassic. Claims of probable Paleozoic rocks at the island of La Tortue (Sprezniosio, 1976; in Pierre, 1982), are doubtful at best. So far the oldest dated rocks reported in the literature yielded minimum ages of 123 to 127 m.y. for a metamorphic event that effected the basement complex of the Duarte Formation in the Dominican Republic (Bowin, 1966; Kesler et al., 1977). These absolute dates thus indicate that the metamorphosed rocks of the Duarte Formation must have been deposited at least during Early Cretaceous time, Neocomian stage. Their maximum age is still unknown. Recent structural studies in the northern areas of the Central Cordillera in the Dominican Republic (Draper and Lewis, 1980), further suggested that the Amina schist may be older than the Duarte Formation. These authors also indicated that there are remarkable similarities between the Amina schist and the schists found at the island of La Tortue. This suggestion may therefore support earlier contention concerning the more ancient character of the rocks found at La Tortue relative to other Cretaceous rocks on Hispaniola, but an exact date is still to be determined.

From the geologic evidence at hand there is, however, general consensus that the Central Cordilleran series are the oldest rocks of the Mesozoic-Cenozoic Hispaniolan island-arc system. The Cul-de-Sac/Enriquillo grabben would mark the natural boundary between the recognized northern island-arc system and the Southern Peninsula, which is now considered an uplifted analog of the adjacent Caribbean crust (Maurrasse et al, 1977, 1979a; Maurrasse, 1982c; Sayeed et al., 1978).

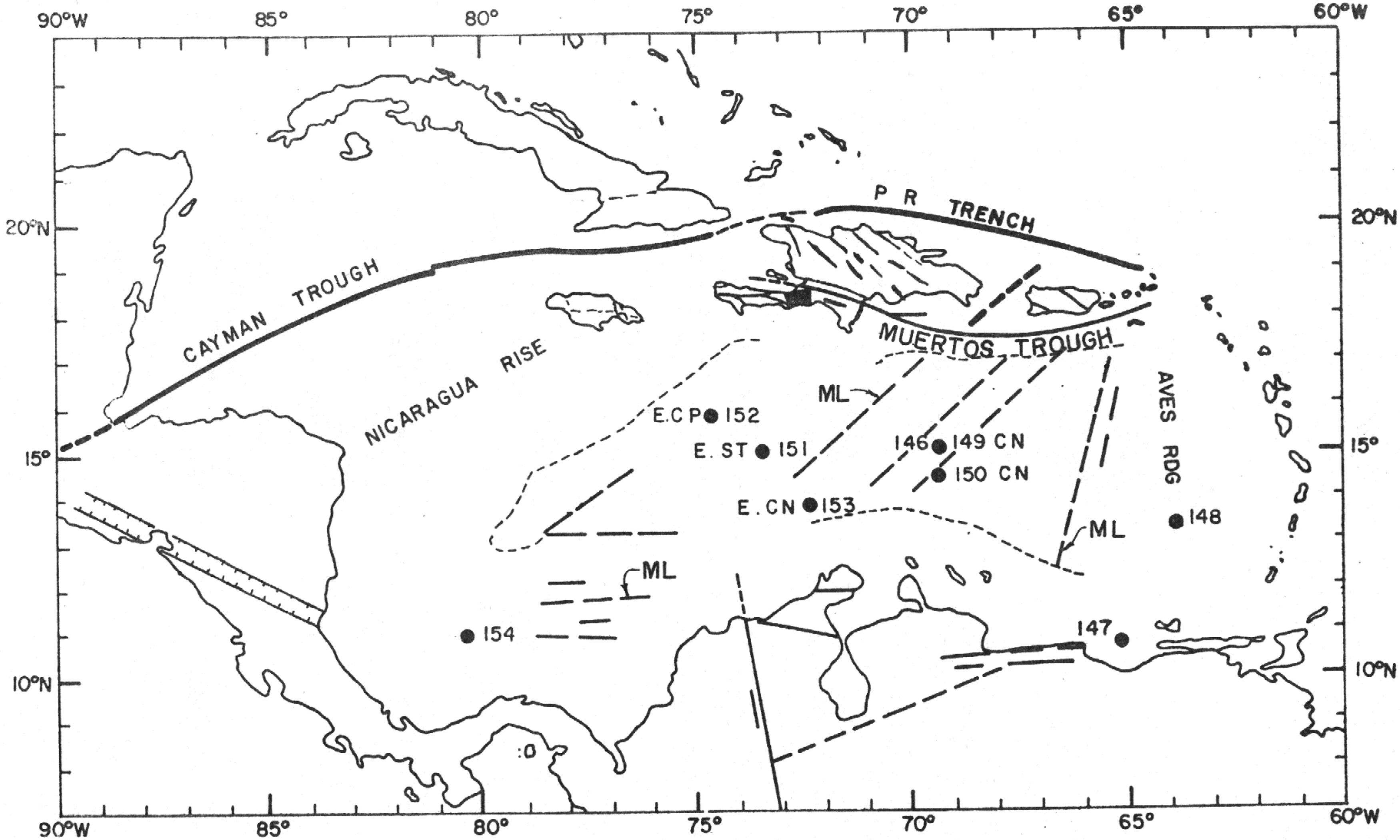
The oldest radiometric dates available for the Southern Peninsula have given a whole rock K/Ar age of 75± 1.5 m.y, Early Campanian to latest Santonian (Sayeed et al., 1978), for a coarse dolerite intruded in the upper part of the Dumisseau Formation (Maurrasse et al., 1979a). The lower part of this formation has also yielded radiolarian taxa which also suggest the presence of the early Late Cretaceous, Turonian stage. Based on the stratigraphic position of the radiometrically dated level, Maurrasse et al, 1979a) further concluded that the lowermost part of the formation may lie within the Early Cretaceous.

Reeside (1947) also described Aptian - Albian Caprinids and Ammonoids from rocks collected by Woodring at a locality northeast of Jacmel. Geochemical data from the Dumisseau rock complex (Maurrasse et al., 1977; Sayeed et al., 1978; Crews, 1978) led to further suggestion that the geotectonic environment of the Cretaceous rocks in the Southern Peninsula was analogous to a back-arc spreading system (Maurrasse, 1982c).

OUTLINE OF THE PRINCIPAL ROCK FORMATIONS OF HAITI

CRETACEOUS - PALEOGENE

TROIS RIVIERES FORMATION: Butterlin, 1954; p. 151. Named After the River "Trois Rivieres" in Northern Haiti.



- - - - - Limit of seismic reflector "Horizon B".

ML Magnetic lineations.

CN CONIACIAN.

E. CN Early CONIACIAN.

E. CP Early CAMPANIAN.

E. ST Early SANTONIAN.

FIGURE 10 - Simplified structural map of the Caribbean region showing limit of occurrence of seimic reflector B", and patterns of magnetic lineations. (Numbers refer to Deep Sea Drilling Project Leg 15 sites)

Type locality: Road Plaisance - Pilate, at 5.1 km west-northwest of the town of Plaisance (Figure 1), in the valley of the Trois Rivieres.

The Trois Rivieres Formation is described to include intercalations of thinnly bedded argillites, brown and gray shales, dark gray to varicolored thickly bedded crystalline limestones with benthic and planktonic foraminifera, occasional rudistids and red or dark-colored radiolarian cherts. Occasional beds of sandstones and conglomerates are also reported to occur in the sequence (Figure 11). The limestone shows extensive calcitic veins related to microfissuration.

Its thickness has been estimated to be no more than 500 meters at the type locality, whereas it is supposed to reach thicknesses of several thousand meters near the border of the Dominican Republic in northeast Haiti (Nicolini, 1977).

Woodring et al., 1924, suggested an Early Cretaceous age for this predominately clastic sequence on the basis of its lithostratigraphic position. According to Butterlin (1960), the formation is in part at least upper Cretaceous, and its topmost levels may lie within the Campanian or even the Maastrichtian. These ages are based on fossil foraminifera.

The Trois Rivieres Formation crops out at several localities in the North of Haiti where it is known at Anse-a-Foleur (on the road from Gros Mornes to Port-de-Paix), in the eastern flanks of the hills adjacent to Cap-Haitian, west and north of Dondon, respectively.

Other unamed rock sequences with clastic facies and of probable Cretaceous age also occur in Northern Haiti, Massif du Nord region (Figures 2, 4). They consist of rhyolitic volcanoclastic and sedimentary deposits, including black shales, volcanogenic breccias, tuffites together with rhyolites, dacites and microgranites. This volcano-sedimentary series is reported to unconformably overly an older ultramafic complex (Nicolini, 1977). Its age has been inferred to be pre-Albian. Similarly, a thick series of polygenic volcanoclastic conglomerates and agglomerates, andesitic lavas of various compositions, red argillites, pisolitic and pseudopisolitic limestones, and limestones with molluscan shell fragments are believed to be probably of Albian age (J. Marie, in Nicolini, 1977). An angular unconformity appears to separate the pre-Albian rocks from the Post-Albian rocks. These rocks apparently continue southeastward into the Central Cordillera in the Dominican Republic. The part composed of pre-Albian black shales has also been suggested to represent the northwestern extension of the gold-hearing uppermost Pueblo Viejo member of the Los Ranchos Formation of Bowin (1966) in the Dominican Republic.

The Los Ranchos Formation has been dated as medial Albian to medial Aptian, based on the presence of the following benthic foraminiferal species: Orbitolina concava texana and Quinqueloculina sp. (Bronnimann, in Bowin 1966). More recent studies of plant fossils found in a lens of black limestone in the Platanal Member underlying the Pueblo Viejo Member also indicate an unspecified Early Cretaceous age for these rocks (C.J. Smiley, written communication, in Field Trip B - Gold deposits of Pueblo Viejo, Rosario Dominicana, S.A.; Field Guide 9th Caribbean Geological Conference, Santo Domingo, p 54).

PERIOD			Type Localities: PLATEAU CENTRAL & MONTAGNES NOIRES	PLAINE DU CUL-DE-SAC	NORTHWESTERN PENINSULA	SOUTHERN PENINSULA
CENOZOIC	RECENT					
	PLEISTOCENE					
	PLIOCENE		HINCHE (Jones, 1918): gravels, clays, sandstones LASCAHOBAS (Jones, 1918): sandstones, sands, clays, conglomerates, marls, lignite North of Lascahobas	MORNE DELMAS (Butterlin, 1950): conglomerates, clays, marls Road from Lalue to Morne Delmas		RIV. GAUCHE (Butterlin, 1954): sand, clays, calcareous sandstones, conglomerates Old road Fauche - Jacmel
	MIOCENE	L	MAISSADE (Jones, 1918): clays, marls, sandstone, lignite Valley of Riv. Blanche	RIV. GRISE (Buttlin, 1950): conglomerates, marls, clays Trail to Bassin General; Habitation Cadet; Morne Jacquot		
		M	THOMONDE (Jones, 1918): sandstones, conglomerates - claystone Near Thomonde			
		E	Mme JOIE (Woodring, 1922): marls, shales, limestones Near Morne Mme. Joie IARC (Kirk, 1940): congl. ls., coraline ls., marls, thinnly bedded ls. CALCAIRE de BASSIN ZIM		LA CRETE (Butterlin, 1954): limestones, sandstones, sand, marls Road from Gonaives to Gros Morne	
	OLIGOCENE	L				JEREMIE (Maurrasse, 1980): pelagic foraminiferal - nannoplankton chalk with chert stringers and occasional shallow-water calcareous turbidites
		M				
		E				
	EOCENE	L			CALC. de PLAISANCE (Vaughan, 1921) = form. d'ENNERY (Butterlin, 1954) = CRETE SALE (part) (Butterlin, 1957): yellow crystalline limestone, conglomerates with pebbles of cretaceous rocks Road from Plaisance to Ennery-St. Michel de l'Atalaye	
		M	PERODIN (Butterlin, 1954): congl. volc. tuffs, clays, ls. Between Trail Pte. Montagne - Maissade and Fie Fie - Mme. Joie ABUILLOT [=ABRIO] (Bermudez, 1949): sandstones, sandy shales, shales, limestones Along Riv. Abrio, Plateau Central			
		E				MARIGOT (Butterlin, 1954): clays-detrital limestones, conglomerates, sandstones. Trail from Marigot to Morne Lindor-Seguin
	PALEOCENE					BELOC (Maurrasse, 1980): pelagic ls., chert, basal polyg. conglomerates. Beloc
MESOZOIC	CRETACEOUS	L			TROIS RIVIERES (Butterlin, 1954): clays, shales, claystones, conglomerates, radiolarites. Rd. from Plaisance to Pilate	MACAYA (Butterlin, 1954): clays, marls, shales, Riv. Glace, Rd. Jeremie-Cayes DUMISSEAU (Maurrasse et al, 1979) basals, pillow lavas, pelagic ls. - chert stringers. Dumisseau - N.E. Kenscoff
		E				

FIGURE 11 - SYNOPSIS OF THE MAIN FORMATIONS IN HAITI.

Thus it is possible that the unamed rocks cropping out in northern Haiti and believed to be of Early Cretaceous age belong in the Los Ranchos Formation.

MACAYA FORMATION: Butterlin, 1954, p. 52, 84. Named aater Pic Macaya in the Massif de la Hotte (Figures 2, 3, 4).

Type locality: Road between Les Cayes and Jérémie, in the valley of Riviere Glace, at 100 meters northeast of the point where the river crosses the road (Figure 12).

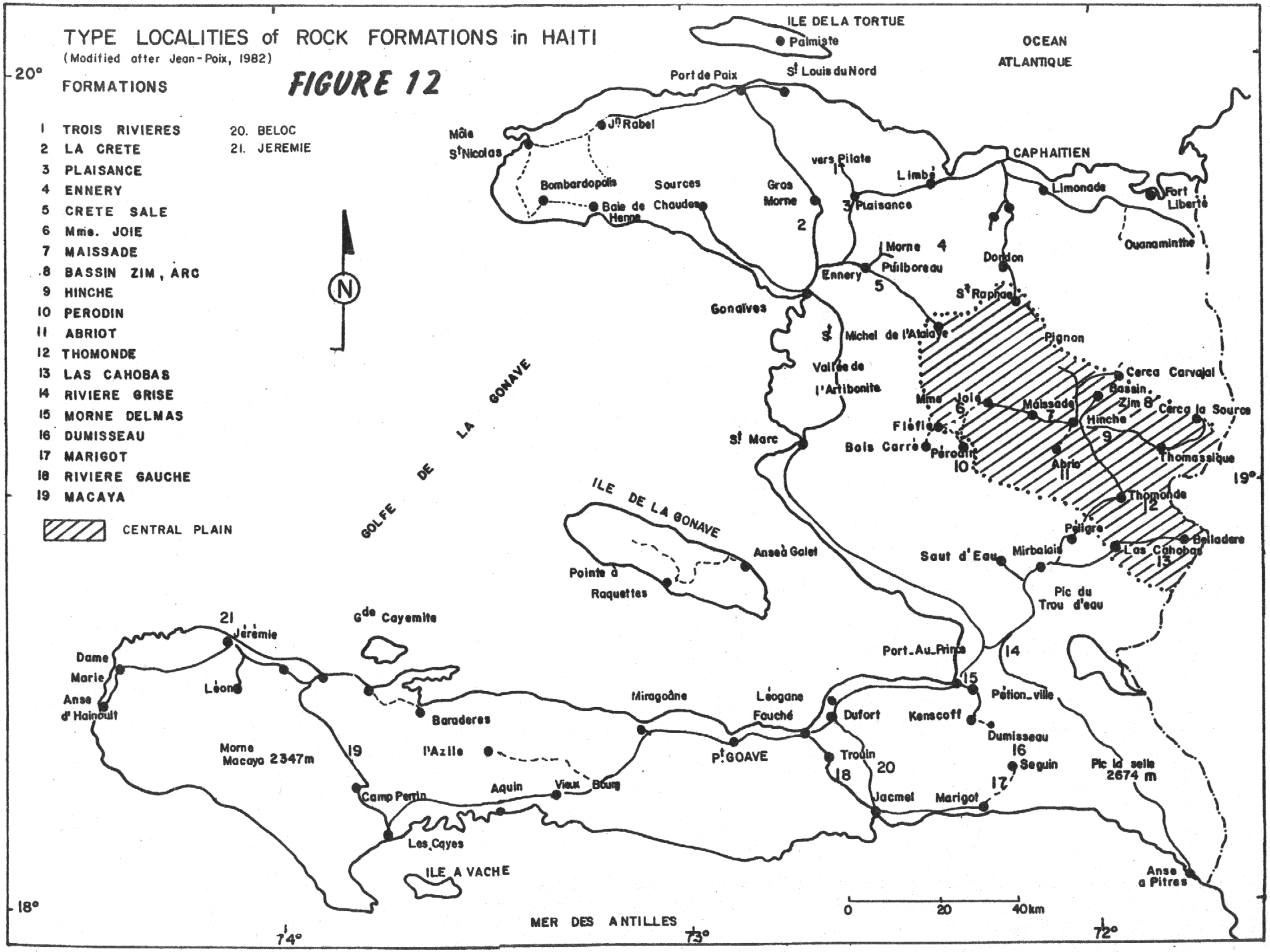
The Macaya Formation comprises a sequence of massive varicolored recrystallized and sparsely silicified limestones with abundant calcite veins. These limestones contain varying amount of clay materials and other impurities which give them different colors, often chocolate brown, green, purplish brown, yellowish gray, or pure white. They are nearly identical to similar lithofacies recovered from drill sites in the adjacent Caribbean Sea during DSDP leg 15 (Edgar et al., 1973; Maurrasse, 1973). The Macaya Formation also includes intermittent argillaceous layers intercalated with the limestones in which the clay content seems to increase toward the base of the series. Occasional radiolarian cherts may also occur as stringers in the limestones (Figure 11).

Butterlin estimated the thickness of the Macaya Formation to be no less than 2000 meters. However, because the Formation is extensively tectonically disturbed, and also because their counterpart in the Venezuela Basin are apparently no thicker than 500 meters, their maximum thickness is expected to be less than a 1000 meters.

As for most of the rock formations found in Haiti, Woodring et al., (1924) were the first to point out the presence of these rock sequences in the Southern Peninsula of Haiti. They assigned an Early Cretaceous age to these rocks. Butterlin (1954) suggested an age of at least upper Maastrichtian for the upper part of the sequence which yielded a planktonic foraminiferal fauna with Globotruncanids, Heterohelicids, and Hedbergellids. The radiolarian fauna in these rocks also suggested a Cretaceous affinity by the presence of Dictyiomitrids. Ayala-Castanares (1969) later assigned a Campanian to Maastrichtian age to these rocks, based on the presence of Globotruncana taxa, characteristic of these stages.

My study of the area of Massanga, northwest of Peak Macaya, further shows that the varicolored limestones of the Macaya Formation may be as old as Santonian. They contain abundant planktonic foraminifera including Globotruncana concavata, Gt. arca, Gt. lapparenti, Gt. falsostuarti, Praeglobotruncana citae. Thus, the Macaya Formation ranges in age from at least the Santonian to the Maastrichtian.

The Macaya Formation crops out essentially in the western regions of the Southern Peninsula of Haiti, west of the Jacmel Fauche depression (Massif de la Hotte). It occurs mostly in the axial regions of the Massif de la Hotte at large, and is underlain by deformed rocks of the Dumisseau Formation (Maurrasse et al., 1979a).


TYPE LOCALITIES of ROCK FORMATIONS in HAITI
(Modified after Jean-Poix, 1982)
FIGURE 12
FORMATIONS
1 TROIS RIVIERES
2 LA CRETE
3 PLAISANCE
4 ENNERY
5 CRETE SALE
6 Mne. JOIE
7 MAISSADE
8 BASSIN ZIM, ARC
9 HINCHE
10 PERODIN
11 ABRIOT
12 THOMONDE
13 LAS CAHOBAS
14 RIVIERE GRISE
15 MORNE DELMAS
16 DUMISSEAU
17 MARIGOT
18 RIVIERE GAUCHE
19 MACAYA
20. BELOC
21. JEREMIE
CENTRAL PLAIN
ILE DE LA TORTUE
Palmiste
OCEAN ATLANTIQUE
Port de Paix
St Louis du Nord
Môle St Nicolas
Jn Rabel
Bombardopolis
Baie de Henne
Sources Chaudes
Gros Morne
vers Pilate
Plaisance
Limbé
CAPHAITIEN
Limonade
Fort Liberté
Ouanaminthe
Dondon
Morne
Puilboreau
Ennery
Gonaïves
St Raphael
St Michel de l'Atalaye
Pignon
Vallée de l'Artibonite
Cerca Carvajal
Bassin Zim
Mme Joie
Maïssade
Hinche
Cerca la Source
Fiéfié
Bois Carré
Perodin
Abrio
Thomassique
St Marc
Thomonde
GOLFE DE LA GONAVE
ILE DE LA GONAVE
Anse à Galet
Pointe à Raquettes
Péligre
Belladere
Saut d'Eau
Mirbalais
Las Cahobas
Pic du Trou d'eau
Gde Cayemite
Jérémie
Dame Marie
Anse d'Hainault
Léon
Baraderes
Port_Au_Prince
Pétion_ville
Miragoâne
Léogane
Fauché
Dufort
Kenscoff
Dumisseau
Morne Macaya 2347m
l'Azile
Pt GOAVE
Trouin
Seguin
Pic la selle 2674 m
Camp Perrin
Aquin
Vieux Bourg
Jacmel
Marigot
Les Cayes
ILE A VACHE
Anse a Pitres
MER DES ANTILLES
0 20 40km
20°
19°
18°
74°
73°
72°

DUMISSEAU FORMATION: Maurrasse et al., 1979a, p. 71, 83. Named after the hamlet of Dumisseau, southeast of Kenscoff, in the Massif de la Selle (Figures 8, 12).

Type locality: Hills of Dumisseau, east and west of the Saint Dominique Church, at Haiti meter grid 792,500 mE; 2,038,500 mN, and 791,300 mE; 2,039,300 mN to 2,038,700 mN respectively.

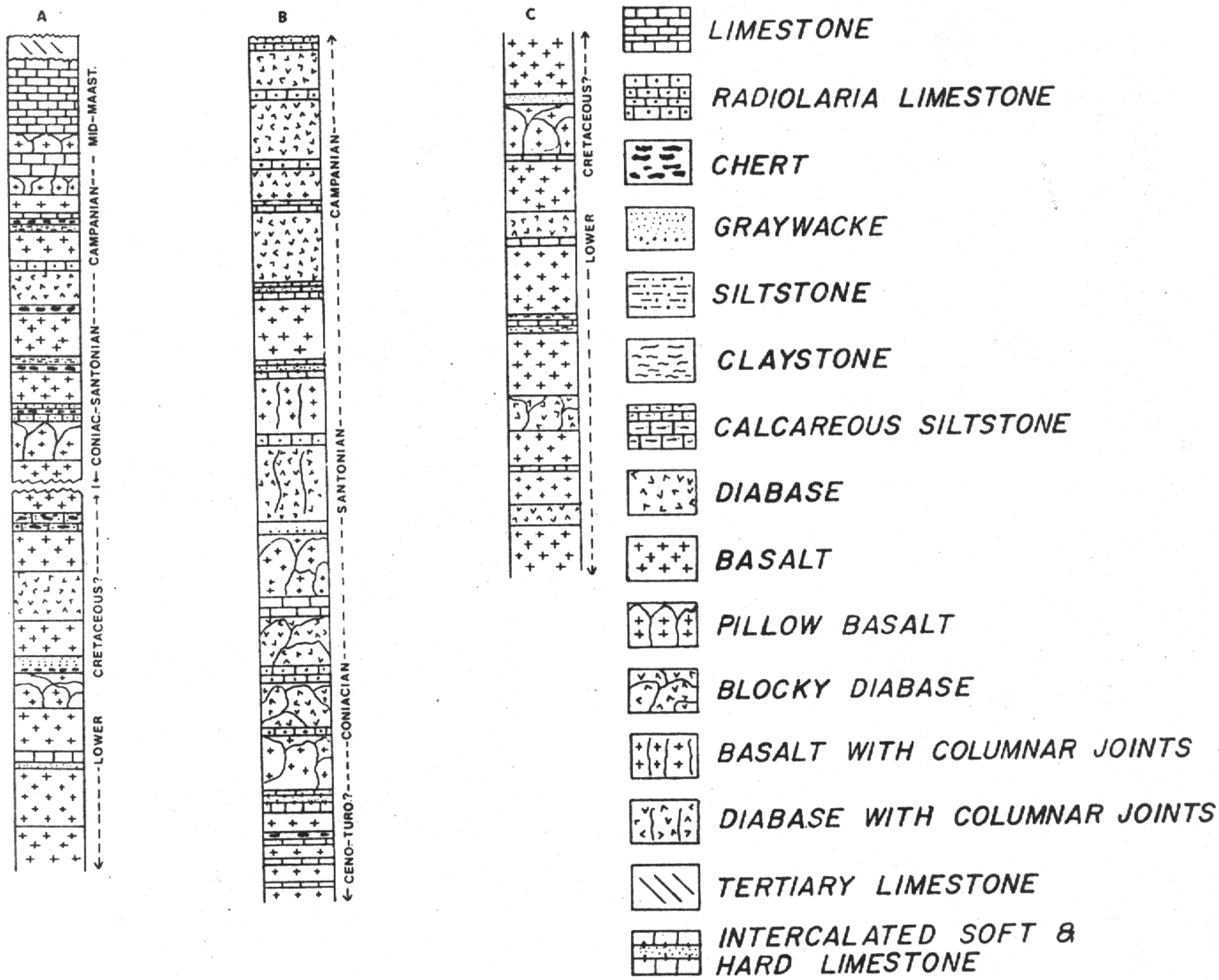
The Dumisseau Formation includes the upper Saint Dominique Member and a lower unamed Member. The formation as a whole is essentially characterized by a sequence of interbedded pillowed and non-pillowed basalts, dolerites, pelagic limestones, intrabasinal volcanogenic turbidites, varicolored cherts and siliceous silstones (Figure 11). The sequence becomes more calcareous toward the top. Although shallow-water limestones including Caprinids and Ammonoids have been reported from a locality north of Jacmel (Reeside, 1947), no shallow-water facies has been found at the type locality. The uppermost part of the Saint Dominique Member consists predominately of grayish orange (10YR7/4) to yellowish gray (5Y7/2) limestones and chalks, varying also to medium gray (N5) and medium olive gray (5 Y 5/1). Silicification pervades all the calcareous beds, although true chert stringers are rare in the topmost thirty meters or so of the exposed sequence at Dumisseau. Most of the calcareous layers can be described microscopically as sparse fossiliferous micrites, but occasional beds are truly packed foraminiferal-radiolarian micrites. These grain-supported layers usually display a sandy texture and slighly graded bedding, much in the same manner as similar layers described in the pelagic limestones recovered at DSDP Leg 15, Site 146/149 (Figure 10) in the Venezuela Basin (Maurrasse, 1973, Schneiderman, 1973).

The sedimentary layers of the lower Member are mainly greywacke with graded bedding and cross laminations, shales, silstones, and occasional claystones of intrabasinal volcanogenic origin. Chert stringers usually show gradation from dispersive and selective silicification of allochems to pervasive silicification of the matrix in the calcareous layers. Chertification is thus a progressive replacement of the calcareous constituents by microcrystalline quartz (Maurrasse et al., 1979a). Cherts of the Dumisseau Formation are also much the same as those recovered at different levels in the pelagic sequences of the Caribbean Sea (DSDP, Leg 15, op. cit.), particularly those found at Sites 146/149, 152, 153 (Figure 10).

The igneous rocks range in grain size from microcrystalline to doleritic in dikes and sills that transect, or are concordant with the sequence. Occasional gabbroic intrusions occur interspersed in the formation, while lherzolite may occur in limited expanse toward the base of the Lower Member. The dolerites, like the basalts, exhibit glomeroporphyritic, ophitic and intergranular textures. Groundmass in these rocks is composed essentially of clinopyroxenes, olivine and opaques. Some dolerites also display characteristic variolitic structure in which the plagioclase phenocrysts are radially arranged, diverging from a common center, and all immersed in the ground mass of mafic minerals. A given diabasic unit may show variolitic structure near the contact zone with the adjacent unit, while its interior portions have intergranular and intersertal textures. The gabbros and lherzolites show primary cumulate textures with cumulate of olivine and

FIGURE 13

Composite Section of the Dumisseau Formation



Schematic lithologic representation (not to scale) of sequences at A: St. Dominique ridge; discontinuity in the column does not correspond to an unconformity but rather stresses the composite character of the sequence described at this ridge. B: hill east of St. Dominique; C: the section of the lower member exposed at Ravine Nan Roseau

(From Maurrasse et al., 1979)

clinopyroxene, and intercumulus plagioclase (Maurrasse et al., 1977; 1979a).

The geochemical characteristic of the igneous rocks point to their abyssal tholeiitic affinities (Maurrasse et al., 1979a).

Woodring et al. (1924), were also the first to notice the presence of sedimentary layers and cherts in the igneous complex of the Southern Peninsula. They assigned a Late Cretaceous age to these rocks. As pointed out earlier, recent studies of these rocks indicate that the maximum age of the formation lies probably within the late Early Cretaceous, or early Late Cretaceous Turonian stage. The lower member has indeed yielded probable Heterochelicids, and taxa of the families Planomalinidae (*Globigerinelloides* sp.) and Rotaliporidae (*Hebergella* spp, *Rotalipora* spp.), indicative of an Early Cretaceous age. Furthermore, the radiolarian fauna in these rocks include species such as *Crucella* cf. *cachensis*, *Crucella* sp. (affinity *Crucella* sp., Foreman, 1973, Pl. 13, figures 18, 19), and *Haliodictya* aff. *hojnosi* which indicates age ranging from the Early Cretaceous to the early Late Cretaceous, Turonian stage. The lower part of the Saint Dominique Member lies within the Cenomanian, or possibly within latest Early Cretaceous, as suggest the foraminiferal fauna which includes *Hedbergella planispira*, *H. amabilis*, *Praeglobotruncana* spp., *Ticinella roberti*, and Radiolaria of the *Stichomitra asymbatos* group.

The thickness of the Dumisseau Formation as estimated in the type area is reported to exceed 1.5 kilometers (Maurrasse, et al, 1979a). Outcrops of this formation occur along most of the axial region of the entire Southern Peninsula. Post depositional, and synformational deformations within the formation can be seen to increase westward in the Peninsula. In some areas, intense deformation led to a tectonic melange (Coleman, 1977). Such an example can be seen along the road from Carrefour Dufort to Jacmel (figure 9).

Relationship between the Dumisseau Formation and the Caribbean Sea Crust

Until the results from drilling in the Caribbean Sea (Edgar et al., 1973), most interpretations of the composition of the Caribbean crust relied essentially on seismic reflection and refraction surveys (Officer et al., 1959; Ewing et al., 1960; 1967; Edgar et al., 1971), and spot samples recovered by the Ewing piston coring method (Ewing et al., 1965). The seismic surveys recognized the existence of a smooth acoustic basement underneath normal acoustically transparent sediments in the Caribbean Sea. This reflector was equated to similar acoustic features in the Pacific and the Atlantic Oceans termed Horizon B and Horizon B′, respectively; hence, the Caribbean reflector was named B". Weaker reflectors detected underneath the Caribbean B" reflector, were thus designated sub-B" reflectors. By the same analogy, a shallower reflector which occurs in the pelagic sediments above the B" horizon marker, was named A". Samples from exposed outcrop of A" at the Beata Escarpment, on the west side of the Beata Ridge, were analysed prior to the Deep Sea Drilling expedition in the area, and were found to correspond to a silicified level of a radiolarian limestone. Thus the A" horizon could be correlated with the presence of cherts at this level.

The Deep Sea drilling results corroborated the previous finding, as A" was actually due to the impedance contrast between the softer non-silicified pelagic sediments and the harder chert layers, which appear nearly consistently in medial Eocene sediments. Average sound velocity in sediments above A" was found to be 1.63 Km/sec, whereas average sound velocity in the interval between A" and B" is 2.5 to 2.6 Km/sec, with values as low as 1.9 Km/sec. In contrast to these low-velocity materials, sound velocity in the cherts may be as high as 5.67 km/sec (Boyce, 1973). Rocks comparable to the A" horizon also occur above the Dumisseau Formation.

The drilling results also showed that Horizon B" could be correlated with tholeiitic basalts and doleritic sills intercalated with, and overlain by pelagic sediments of Coniacian to Campanian ages (Edgar et al, 1973). The crust below B" was unfortunately not reached. The uncertainty concerning the exact nature of the sub-B" reflectors thus remained unsolved. The reflectors were generally suggested to be composed of intercalated igneous and sedimentary rocks (Edgar et al., 1971; Hopkins, 1973; Ludwig et al., 1975; Case, 1975; Matthews and Holcombe, 1976; Ladd and Watkins, 1977).

The possible relationship between the complex sedimentary and igneous rocks of Cretaceous age in the Southern Peninsula and those in the Caribbean Sea became meaningful as a result of the writer's participation in DSDP Leg 15. It was during this expedition that remarkable similarities between the deep-sea materials and those previously observed at the Southern Peninsula were noted. Subsequent onshore studies of the Caribbean Sea materials, and field and laboratory analyses of the Southern Peninsula rocks further Substantiated this initial inference (Edgar et al., 1973; Maurrasse, 1976, Maurrasse et al., 1977; 1979a). Further lithologic sutdies, and paleomagnetic analyses of these rocks (Kent and Maurrasse, 1982), also corroborate the analogy. Recent multichannel seismic studies in the Caribbean Sea (Diebold et al., 1981; Stoffa et al., 1981; have also brought corroborative evidence to the effect that the seismic character of the Caribbean crust below acoustic reflector B" is in agreement with the lithologic sequence observed in the Dumisseau Formation.

The Dumisseau Formation, therefore, provides an exceptional opportunity to analyze a land analog of the elusive sub-B" reflectors. As pointed out hereinbefore, because the geologic data at hand supports the analogy, the Dumisseau Formation is considered to represent materials analogous to those of the adjacent Caribbean crust. These rocks thus show evidence that the Southern Peninsular is a portion of the Caribbean crust uplifted through differential vertical motion taking place along the northern boundary of the Caribbean megashear. Dismembered limestone and chert layers in the igneous matrix indicate that the structures were formed as a result of increased polyphase deformation from initially ductile to more brittle in late stages. Deformation is more intense westward as these areas were closer to the accretionary prism of the Nicaragua Rise-Jamaica subduction Zone (Maurrasse, 1982c).

<u>BELOC FORMATION:</u> Maurrasse, 1980a, p.25; 1982a, p.184,188. Named after the village of Beloc located immediately north of the formation (fig.12).

<u>Type locality:</u> Mountains South of Beloc, at the westernmost end of the Massif de la Selle, at Haiti meter grid 755,600 mE; 2,031,750 mN; close to an altitude of 800 meters on the

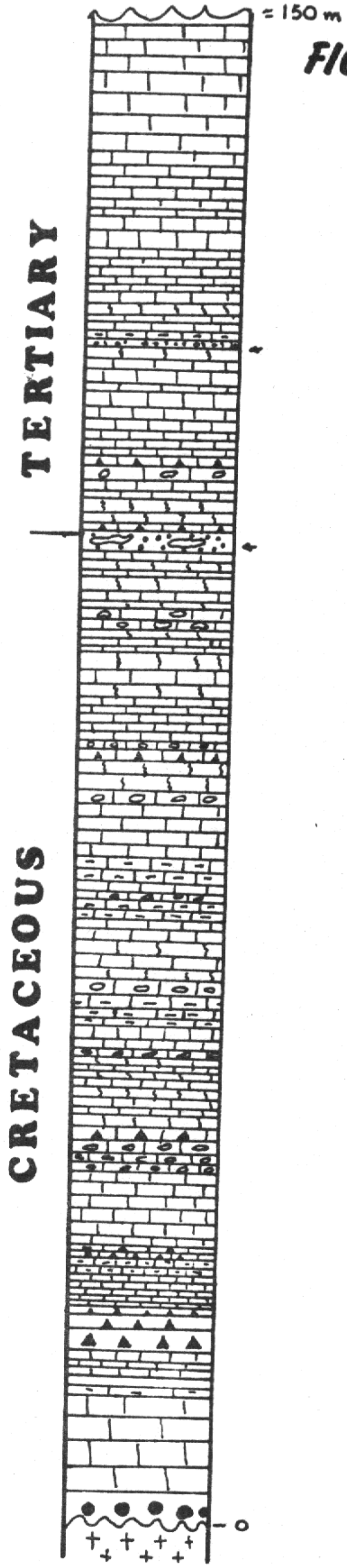
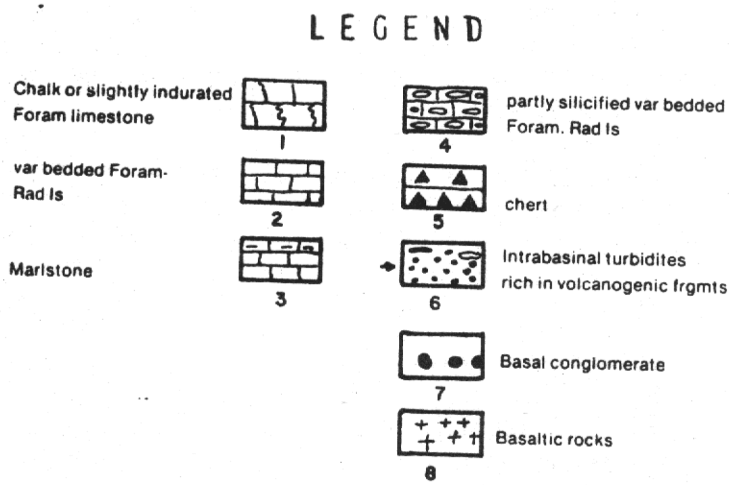


FIGURE 14 : *Composite section of the Béloc Formation*
(Not to scale)

Middle and upper parts of the section crop out along road cuts as shown in Fig.1 Lower part of the section can be found only in deep gullies and stream beds at topographic levels below road cuts.

(From Maurrasse, 1982a)



mountain road from Carrefour Dufort to
Jacmel, and 4 to 5 kilometers south of
the village of Beloc (Figures 2,4,14,15).

Rocks typical of the Beloc Formation include a monogenic basaltic basal conglomerate about 1 to 2 meter thick overlying weathered igneous rocks of the Dumisseau Formation. The conglomerate intergrades with the weathered igneous rocks, and the overlying sequence consists essentially of homogenous pelagic limestones and chalk interbeds. The calcareous rocks are typically very light tan to grayish white color when they are dry, but turn into much darker hues (brownish gray) when wet (Figure 11).

The beds in the lower part of the sequence vary from about 3 cm to 100 cm in thickness, those in the upper part are thinner (Figure 15). Bedding is often only apparent, and is related to differential diagenetic lithification rather than true compositional differences, although there may be minor ones. Similar lithologic characteristics were also found in upper Cretaceous sediments of the Caribbean Sea (Maurrasse, 1973). Despite the apparent lithologic homogeneity of the sequence, several synformational sedimentological disturbances occur at different intervals. The most conspicuous such level occurs about 40 to 50 meters from the base of the series at the type section. It consists of a 50cm thick volcanogenic turbidite showing typical subaqueous flow structures. This turbidite is overlain by a 2 cm thick marl believed to delimit the Cretaceous and the Tertiary (Maurrasse et al., 1979b). Two lesser (less than 2 cm thick) intrabasinal volcanogenic turbidity flow deposits also occur above the main marker bed. Less conspicuous in the limestone sequence are occasional intraformational conglomerates which become visible only on weathered surfaces of the exposed rock. Secondary structures are essentially those related to series of parallel gravity faults and shearing in the rocks during tectonic deformation (Figure 15).

Microscopically, the limestones consist of sparse micrites with variable amount of Radiolaria. Silicification is predominately dispersive, and becomes pervasive only at certain levels within the latest Maastrichtian. Chert stringers are usually very dark brownish gray to dark gray. Again the analogy with cherts recovered at similar stratigraphic level in the Caribbean Sea (Maurrasse, 1973) is most striking.

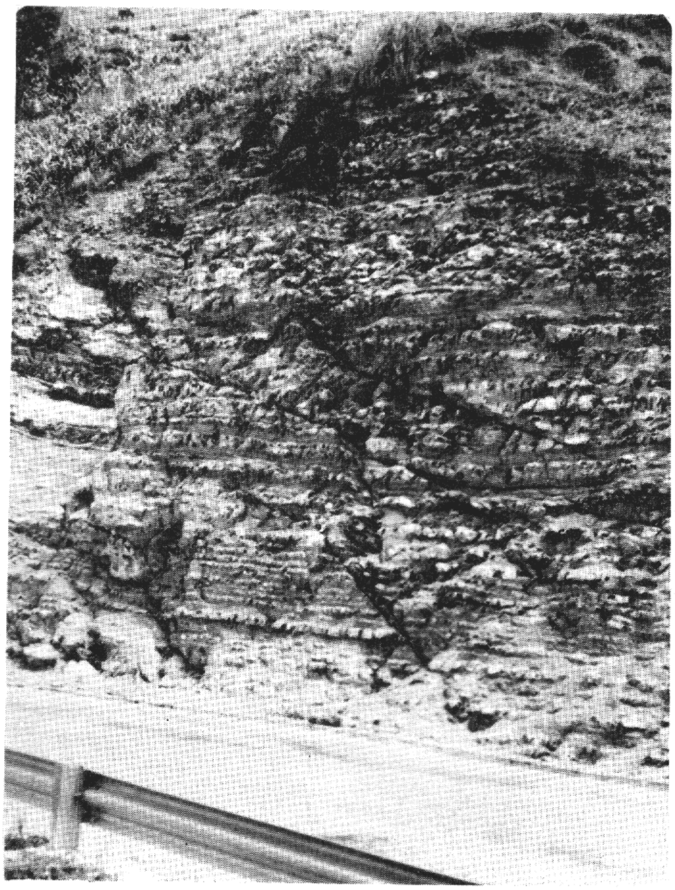
The age of the Beloc Formation ranges from the Late Maastrichtian _Globotruncana contusa_ Zone to the earliest Paleocene, Danian stage, possible the _Globorotalia pseudobulloides_ Zone. The maximum thickness of the formation at the type section is about 150 meters. Its lower boundary lies uncorformably over rocks of the Dumisseau Formation, and its upper limit is undetermined. Although its lower limit is Late Cretaceous at the type section, outcrops of Campanian and older Maastrichtian rocks immediately north of the Village of Beloc suggest that the lower boundary of the Beloc Formation may be diachronous. It may, therefore, be older than Maastrichtian in certain areas, or even intergrade with the uppermost part of the Dumisseau Formation.

FIGURE 15

BELOC FORMATION (TYPE LOCALITY)

a

b



Problems associated with the Cretaceous/Tertiary boundary in the Beloc Formation.

As I pointed out in the preceding paragraph, the lithologic sequence of the Beloc Formation includes a major marker bed which consists of an intrabasinal turbidity deposit. It has been found (Maurrasse et al., 1979b), that the 2cm-thick marl overlying it includes a foraminiferal assemblage attributable to the earliest Danian stage, *Globigerina eugubina* Zone. Typical Danian fauna such as *Globigerina eugubina* and *Globigerina fringa* become conspicuously abundant at that level whereas their presence is either doubtful or the assemblages are so rich in uppermost Cretaceous taxa that the underlying levels can not positively be assigned to the Danian. Despite the fact that the marl layer contains enough of the Danian taxa to warrant its being placed in the Tertiary, it also includes numerous Cretaceous species which are apparently not reworked from older levels (Maurrasse, 1982a). The earliest Tertiary seems to be characterized by a mixture of surviving Cretaceous taxa together with a dominance of the triserial taxon here assigned to *Gumbelitria cretacea*. This taxon is so characteristic of this elusive Cretaceous/Tertiary transition zone at Beloc that it is suggested that the uppermost level of the Maastrichtian and the lowmost Danian stage could be identified as the *Gumbelitria cretacea* Zone.

The nannoplankton flora also give conflicting evidence concerning the Cretaceous/Tertiary boundary at Beloc. Perch- Nielsen (Written communication, 1981) pointed out that "most of the forms normally present in higher numbers in NP_1 (very small *Biscutum* in low latitudes, *M. inversus*, large *Biscutum*, and *Cyclagelosphaera* and *P. sigmoides* in higher latitudes) here occur only in very low numbers or not at all. On the other hand, there are plenty of Maastrichtian forms and obviously some reworked forms that normally disappear near the Campanian/Maastrichtian". The only criterion which may be used to indicate the passage into the Danian is the abundance of *Thorocasphaera*. Perch-Nielsen (op. cit.) further indicates that *Thoracosphaera* is very rare in the samples below the assigned boundary, whereas it becomes rare to few above, and suggests" thus one can assume that these samples can be correlated with samples from other sections in NP_1".

Thus, both the foraminifera and the nannoplanktons indicate degrees of reworking which are somewhat compatible with the sedimentary distrubances observed at this level assigned to the Cretaceous/Tertiary boundary. The absence of certain typical nannoplankton taxa, and the occurrence of supposedly Cretaceous foraminiferal taxa within the assigned Danian remain a puzzle, although the evidence at hand suggests that the Cretaceous Tertiary organisms truly overlapped.

Assuming that an Iridium high is everywhere contemporaneous at the Cretaceous/Tertiary boundary, as it has been proponed in the literature, a similar occurrence in the marl above the volcanogenic marker bed at Beloc is surely the most convincing argument for this level being the boundary (Alvarez et al., 1982). Yet, again some difficulties arise because appreciable Iridium anomaly also occurs in a marl lens within the volcanogenic turbidite below the marl layer (Asaro, oral communication, February, 1982). This peculiarity also remains to be explained.

The volcanogenic bed appears to have come from igneous terranes now lying north of Beloc where the more proximal part of the turbidite contains a larger proportion of older fauna (particularly Campanian fauna) which are reworked from a pelagic chalk. The distribution pattern of the volcanogenic marker bed suggests that it may in fact overlie Cretaceous levels of different ages because of the scouring effects of the turbide flow. Thus, only the distal part of the turbidite lies in a continuous record with the uppermost Maastrichtian and the lowest Danian.

Furthermore, the Beloc Formation which includes a continuous section from Cretaceous to Tertiary also brings evidence in support of early contention (Maurrasse, 1976; Maurrasse et al., 1977; 1978; 1979a) that the major tectonic event in the Southern Peninsula was possibly Pre-Campanian, or early Campanian. These observations are also consistent with unconformities reported in the Dominican Republic (Bowin, 1966). Although large parts of the proto-Hispaniola island arc and its back-arc basin (the site of the future Southern Peninsula) were affected by extensive deformation about Campanian time, emergence must have been limited to certain areas because of block faulting tectonism which has been the dominant tectonic style along this northern edge of the Caribbean plate. It should also be emphasized that a major disturbance does not necessarily imply emergence (even though independent blocks could have come very close to the surface of even been emergent) as attests the pelagic sequence at Beloc.

<u>MARIGOT FORMATION:</u> Butterlin, 1954, p. 57; 106. Named after the village of Marigot, at the southern side of the Massif de la Selle (Figure 12).

<u>Type locality:</u> Northeast of the village of Marigot on the road from Marigot to Seguin.

The lithologic sequence of the Marigot Formation is characterized by the predominance of terrigenous materials of basaltic origin which occur in the different lithofacies of the series. The formation includes varying beds of conglomerates, sandy shales, calcareous sandstones, and clastic limestones (Figure 11). Thicknesses of the different beds usually vary from about 3 cm to 10 cm, with maximum values found in the conglomeratic and limestone beds. The base of the sequence is usually hidden by slope wash, or overlies rocks of the Dumisseau Formation.

The upper part of the formation may intergrade either with very light colored (light yellowish gray to nearly white) lower Eocene biocalcarenites, biocalcirudites, or white thinly bedded white chalky limestones. The coarser limestone facies are rich in benthic foraminifera whereas the chalky facies are rich in planktonic foraminifera. Initially Butterlin (1954) estimated the total thickness of the sequence to be within the range of 900 to 1000 m., but subsequently (1960), he suggested several thousand meters instead. The initial estimates are closer to the real thickness.

The age of the Marigot Formation varies between Paleocene and Early Eocene. The formation is overlain by limestones similar to the lithofacies described as the Neiba Formation (Dohm in Bermudez, 1949, p.21) in the Dominican Republic, and in other cases by the limestone facies of the Plaisance Formation (Vaughan 1921, p. 64).

The Marigot Formation is found in the southern areas of the Massif de la Selle only. Other rock outcrops assigned to this Formation (Butterlin, 1954, 1960) are talus slope breccias at the base of the major fault scarps (Maurrasse et al., 1979a) of the La Selle Fault System.

ABUILLOT FORMATION: Bermudez, 1949, p.19. Named after River Abrio at the southern edge of the Plateau Central in Haiti (Figure 12). Bermudez gave the name of the formation based on field notes of Atlantic Refining Company geologists who mispelled the name of the river.

Type locality: 15 km southwest of Hinche along the valley of river Abrio where it transects the northeastern foothills of the Montagnes Noires (Figure 2,4).

The Abuillot Formation consists of series of brown sandstones, sandy shales, shales and limestones (Figure 11). The base of the formation is marked by a nonconformity with older volcanics, and is apparently conformably overlain by upper Eocene limestones. Its total thickness could be up to a thousand meters as determined from bore holes by the Atlantic Refining Company.

Bermudez (1949) listed the following species as typical of the formation: Alabamina haitiensis, Anomalina abuillotensis, Bathysiphon abuillotensis, Bolivina capdevilensis, Bulimina quadrata, Clavulinoides excurrens, Coleites abuillotensis, Dorothia principis, Globorotalia aragonensis, Gonatosphaera principis, Loxostomum applinae, and Stichocibicides aricki. He suggested an early Eocene age for the formation. Actually the presence of Globorotalia aragonensis indicates an age of late Early Eocene to Middle Eocene.

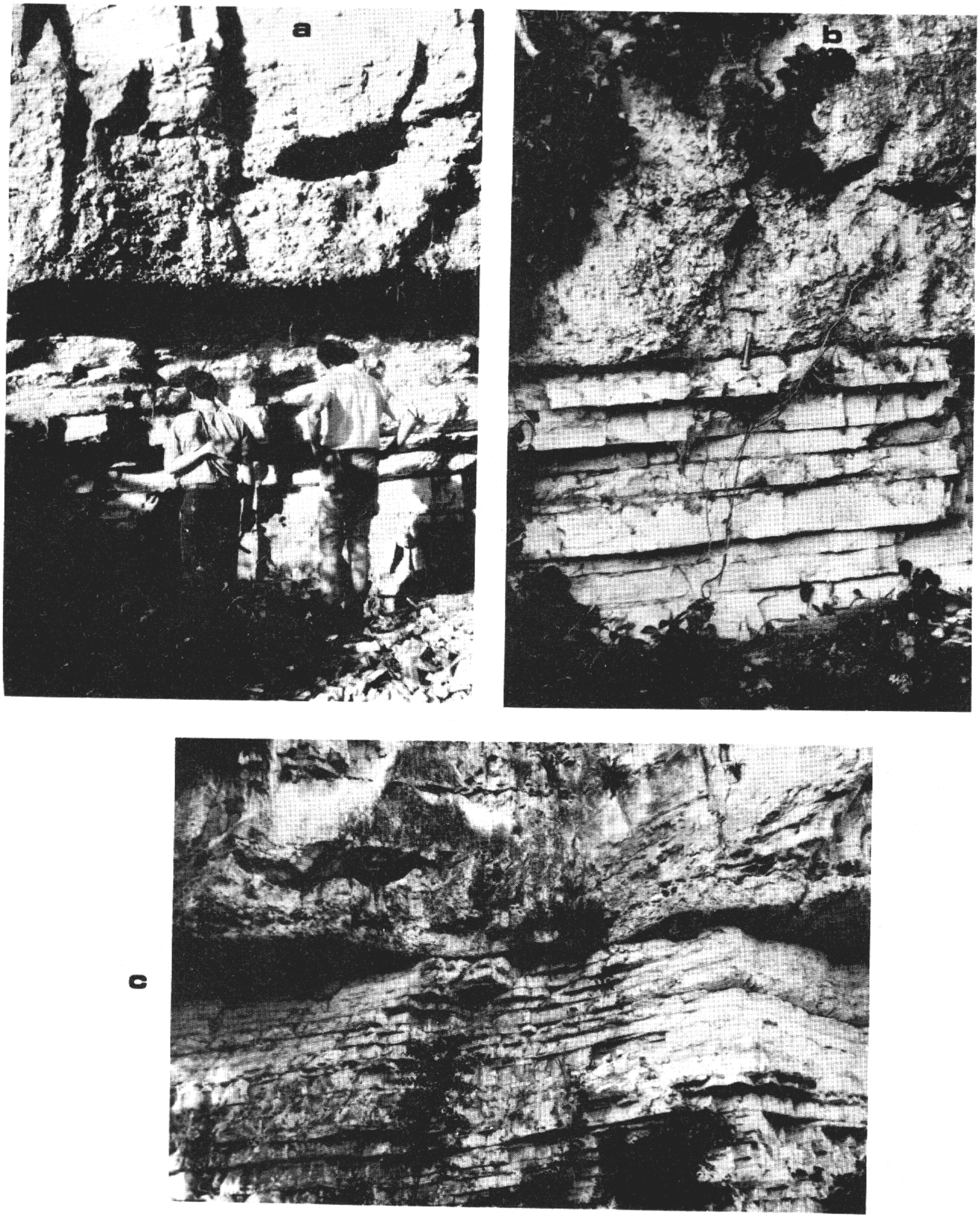
Facies of the Abuillot Formation crop out in numerous areas of the island north of the Cul-de-Sac/Enriquillo graben, and particularly in the Montagnes Noires.

PERODIN FORMATION: Butterlin, 1954, p.433. Named after the village of the same name in the central areas of northwestern Montagnes Noires (Figures 2,4,12).

Type Locality: Perodin and surrounding areas at the highest elevations in the Montagnes Noires.

The lithologic sequence of the Perodin Formation consists of a thick basaltic and andesitic tuff series intercalated with varicolored marls,

FIGURE 16



Shallow-water materials deposited as turbidites in deep-water facies near Ennery.

shales, brown and gray limestones with chert stringers (Figure 11). The series of sandy shales, occasionally interstratified with sandstones and argillites rich in volcaniclastics have also been suggested by Butterlin (1960) to be the possible analogs of similar series in the Abuillot Formation (cf, preceding paragraph). Butterlin indicated that the upper part of the formation is conformably overlain by medial and upper Eocene limestones, while the bottom part of the formation may intergrade with the Abuillot Formation. He also pointed out that the Perodin Formation in the type area shows fault contact with rocks believed to be Oligo-Miocene (limestones of the Madame Joie Formation type of lithofacies, as will be described in subsequent paragraphs).

Butterlin assigned a Middle Eocene age to the Perodin Formation on the basis of the occurrence of benthic foraminiferal taxa such as Euconuloides wellsi (his locality HPS 54-55). Subsequently, Butterlin (1960) also figured younger benthonic foraminiferal taxa which he reported from samples of the Perodin Formation. These taxa include, among others: Heterostegina antillea (his locality HPS 35), Spiroclypeus bullbrooki (his locality HPS 35), Lepidocyclina canelli (his locality HPS 35) and Miogypsina antillea (his 35 locality HPS 56) all reported to indicate an Oligo-Miocene age. Unless these samples were mislabelled and came instead from the adjacent lithofacies of the Madame Joie Formation, the Perodin Formation could be as young as Middle Miocene.

Facies typical of the Perodin Formation crop out over an area about 10 kilometers wide in northwestern Montagnes Noires along the trail going from Petite-Montagne/Maissade to the east, to Bois-Carre-Fiéfié/Madame Joie to the west. The thickness is estimated to be no less than 1000 meters (Butterlin, 1960).

PLAISANCE FORMATION: Vaughan, 1921, p. 64. Named after the town of Plaisance at the foothills of the northern flank of Morne Puilboreau in the Massif du Nord (Figure 12).

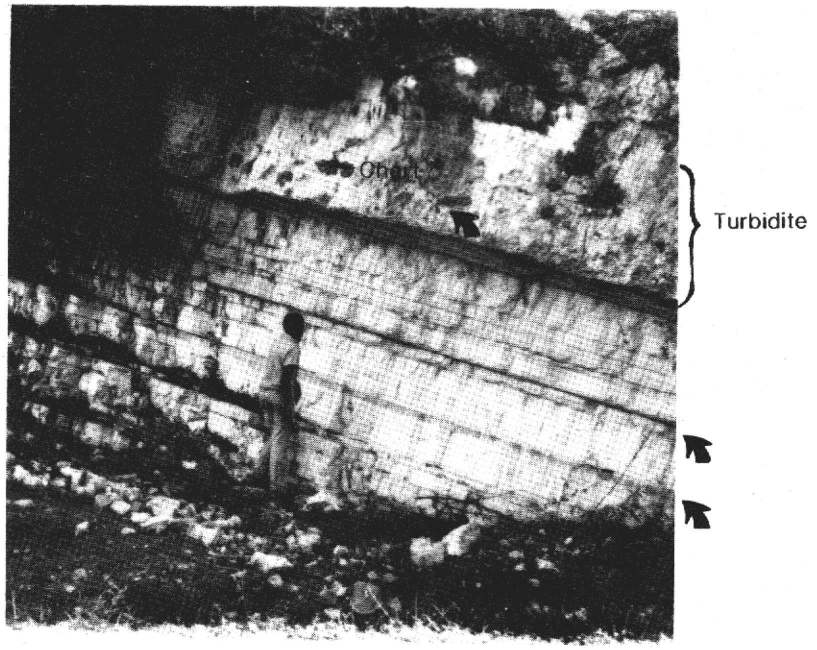
Type locality: On the road between Plaisance and Ennery at an altitude of 705 meters.

The plaisance type of lithofacies, as assigned by Vaughan, consists predominately of thickly bedded biocalcarenites, mainly very pale yellowish brown (10 YR 7/2) to a light pinkish brown (between light brown - 5 YR 6/4, and pale yellowish brown -10 YR 6/2). The basal beds consist of medium coarse conglomerate composed of rounded igneous pebbles and argillite interbedded with shaly material, and with lenses of impure brownish-yellow limestone, which also contains detrital fragments (Woodring et al., 1924, p. 102). Its thickness has not been determined, but is probably less than 500 meters.

As pointed out by Woodring et al., 1924, the Plaisance limestones facies is remarkably rich in benthonic foraminifera of the species Dictyoconus puilboreauensis and Dictyoconus codon. These limestones are also rich in Echinoid, and Pelecypod shell fragments. The age of the formation is Middle Eocene.

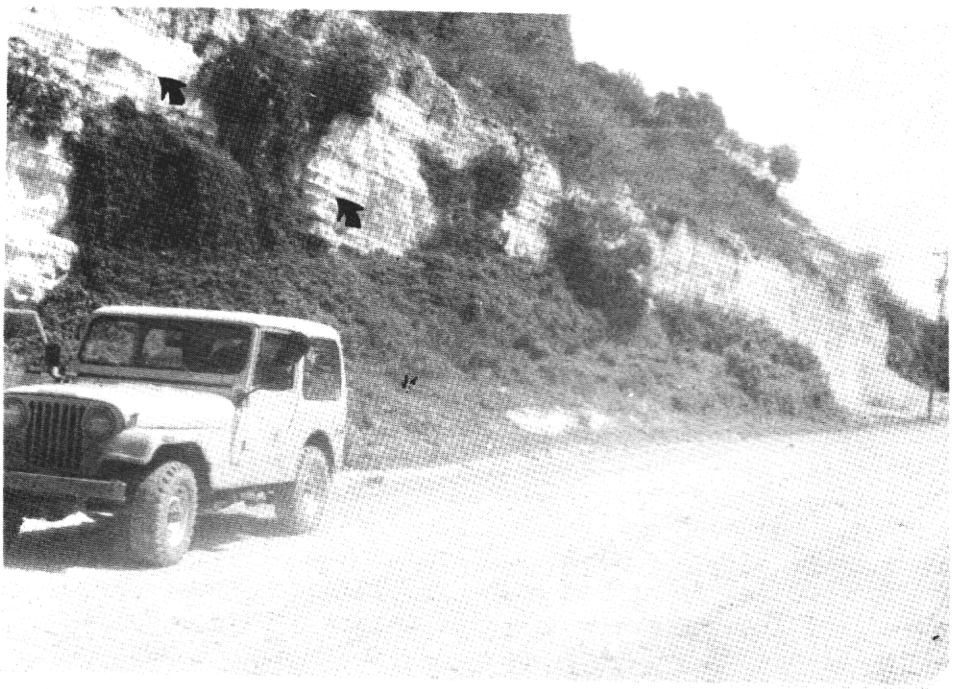
FIGURE 17

A



Turbidites of shallow-water materials, from typical Plaisance Formation limestone, in deeper water equivalent. Near Ennery. Arrows point to thinner silicified turbidites, and chert stringers.

B



Jeremie Formation at type section. Entrance of city of Jeremie.

The Plaisance limestone facies is very widespread over the island of Hispaniola, and it represents a typical shallow- bank deposit. This facies forms most of the prominent mountain ridges and crests in the island.

I also incorporate with the Plaisance Formation the Crete Sale Formation (Butterlin, 1957), and part of the Ennery Formation (Butterlin, 1954) on the sourthern flanks of Morne Puilboreau and adjacent hills, which intergrade with the typical Plaisance limestone facies. The main facies of the assigned Ennery Formation of Butterlin can be correlated with similar facies described as the Neiba Formation in the Dominican Republic (Dohm, in Bermudez, 1949, p.21). These limestones occuring at the southern foothills of Morne Puilboreau are typically thinnly bedded (Figures 15,17a) and include intermittent turbidites composed of materials of the shallower-water Plaisance lithofacies. Thus, the lithofacies near Ennery are here equated to the Neiba type of lithofacies collateral of the lithofacies characteristic of the Plaisance Formation. The latter apparently developed on paleobank systems which came to existence concomittantly with the tectonic dislocation of the island arc in Early Paleogene. Such banks developed south of the Cul-de-Sac graben as well. The back-arc basin also became dislocated due to progressive deformation along the northern boundary of the Caribbean plate. The shallow-water limestones which developed over these banks at different times within the Paleogene, now constitute the dominant relief of most of the physiographic units of high topography described hereinbefore. In the Massif du Nord (figure 2) the deeper-water facies occur southward and southeastward of the Plaisance facies which developed over igneous rocks basement forming the present backbone of this mountain chain.

JEREMIE FORMATION: Maurrasse, 1980, p.26; 1982, p.184,195. Named after the city of Jérémie on the northwest coast of the Southern Peninsula (Figure 12 and 17B).

Type locality: Entrance of the city of Jérémie (Figure 16B). A hypostratotype occurs between 7 and 10 kilometers from Marché Léon, south-southeast of Jérémie.

At the type locality and the hypostratotype, the Jérémie Formation consists predominately of nannoplankton-foraminiferal chalk with very sparse Radiolaria. The chalk is essentially white to very slightly pinkish (Figure 11). Thin silicified layers (2 - 12 cm thick), which often occur as light brown cherts, are intercalated at variable intervals in the chalk layers (Figure 17B). Silicification at these levels is gradational and pervades the chalk adjacent to the chert stringers.

There are no apparent primary structures in the chalks. Secondary sedimentary structures are primary related to minor dislocation caused by normal faults which affect most of the sequence at the type section.

At the type locality there are no apparent stratigraphic boundaries as the formation is overlain by slope wash, and its lower part dips gently below the level of the road (Figure 17B). Nonetheless, in the hills southeast of Jérémie the formation is unconformably overlain by coral rocks of probably

FIGURE 18 : Map showing known outcrops of the Béloc Formation and Jérémie Formation in western Hispaniola (From Maurrasse, 1982a).

Pleistocene age. The age of the Jérémie formation is determined on the basis of a well diversified planktonic foraminiferal fauna which includes among others: Globorotalia siakensis, Gl. opima nana, Globigerina ciperoensis aff. angustiumbilicata, G. ampliapertura, G. venezuelana, G. tripartita, G. rohri, Globorotaloides suteri, Catapsydrax unicavus, and Chilogumbelina cubensis, indicative of a Late Oligocene age. The sequence at the type locality is inferred to range in age from late Middle Oligocene to early Late Oligocene. Also, because medial Eocene eupelagic facies occur farther south in the Southern Peninsula near Jérémie, it is inferred that the base of the Jérémie Formation may lie within the upper Eocene pelagic limestone series of this region.

Facies attributable to the Jérémie Formation also occur in the Northwestern Peninsula (Figure 18), on the road from Bombardopolis to Baie-de-Henne, and on the road Jean-Rabel to Anse Rouge. At these locations, facies of the Jérémie Formation yielded foraminiferal fauna indicative ages ranging from at least Early Eocene (Globorotalia aragonensis Zone), to the Early Oligocene (Hastigerina micra Zone). The same facies occurs in great abundance at the eastern end of the La Selle-Baoruco block, notably south of Thiotte, and beneath the coral cap south of Oviedo (Figure 18). In these areas it is also of Oligocene age and possibly reaches the Early Miocene Globigerinoides primordius Zone. Limited outcrops of this facies also occur south of Beloc, and farther west near the city of Miragoane, on the road to Paillant (Bauxite mining area of the Plateau de Rochelois)(Figure 18). In the latter area the Jérémie Formation includes intercalations of thin beds of coarse biocalcarenites, which are turbidity deposits composed of shallower-water benthic organisms. These beds occurr at a frequency of 1 to 1.5 meter interval in the sequence. These turbidites are comparable to the shallow-water biogenic turbidites present in the Neiba facies near Ennery (Figures 16, 17A), as previously mentioned.

The Jérémie Formation thus represents a deeper-water equivalent of the Neiba Formation, which in turn is deeper than the Plaisance type of facies, as previously discussed.

LA CRETE FORMATION: Butterlin, 1954, p.63; 181. Named after Morne La Crête, between Gonaives and Gros Mornes in the Northwestern Peninsula (Figure 12).

Type locality: Road Gonaives - Gros Mornes, at an altitude of 235 meters on La Crête Hill.

The La Crête Formation consists of hard, sandy yellow limestones, often including coralline fragments, and intercalated with argillaceous limestones, thinnly bedded gray and brown marls, and sandstones which include volcanic and limestone fragments. (Figure 11).

North of the type locality the formation includes a volcanogenic basal conglomerate unconformably overlying lower Oligocene limestones (Butterlin, 1960). It is also reported to be uncorformably overlain by Miocene and Pleistocene series. Its estimated thickness is about 500 meters.

Butterlin (1954, 1960) assigned an Oligo-Miocene age to the La Crête Formation on the basis of the occurrence of the following benthonic foraminiferal taxa: Amphistegina sp. aff. A. Lessoni, Gypsina pilaris, Miogypsina antillea, Lepidocyclina canellei, and Madreporaria such as Heliastrea canalis, Placoenia tampaensis var silecensis, and Siderastrea conferta.

I studied numerous samples from outcrops of this lithofacies on the road Gonaives - Gros Mornes and found that they consistently yielded planktonic foraminiferal fauna indicative of the Early Miocene Globorotalia kugleri Zone and younger. Thus this formation may in fact be of Miocene age only.

Facies of the La Crete Formation are found in the Northwestern Peninsula of Haiti.

NEOGENE

ARTIBONITE GROUP

Woodring (1922, p.6) introduced the term Artibonite Group to include most of the Formations of the Plateau Central previously studied by Jones (1918), and to which he added the Madame Joie Formation. In the present summary I include all the Neogene Formations of the Plateau Central, which are also found in the Artibonite basin areas, under the heading of Artibonite Group. (Figure 11).

ARC FORMATION: Kirk, 1940, in Van den Bold, 1974, p.536. Arc is an acronym for Atlantic Refining Company.

Type locality: Not designated by original author. Van den Bold (1974, 1981) used a lithologic sequence along the Agoiadome River in northeastern Plateau Central as the type section (Figure 12). His choice is based on earlier work of ARCO geologists.

The Arc Formation consist of a lower part of basal conglomerate and bedded limestone with shale partings; a middle part of sandy marl with flaggy limestone layers (only partly exposed in the Agoiadome section); and an upper part of coralline limestone, conglomerate and interbedded marl (Van den Bold, 1974, 1981) (Figure 11). According to Van den Bold 1974, the lower part of the formation probably overlies the Bassin Zim limestones, which are in turn reported to unconformably overlie medial Eocene limestones (Butterlin, 1960). The upper part of the Arc Formation is overlain by the Las Cahobas Formation (see following paragraphs). The total thickness of the formation, excluding the Bassin Zim limestones, is approximately 1300 meters: lower part approximately 200 meters; medial part 800 meters; upper part 300 meters (Van den Bold, 1981). The thickness of the Bassin Zim limestones is undetermined.

Assuming the Bassin Zim limestones are incorporated in the Arc Formation, its lower limit thus lies within the Oligocene, because Butterlin (1960) reported the presence of Lepidocyclina giraudi, Lepidocyclina yurnagunensis, and Lepidocyclina undosa in these limestones. The Arc Formation proper, as reported by Van den Bold (1981), lies within the early Miocene Zones N5 and N6 (Catapsydrax dissimilis and Catapsydrax stainforthi Zones respectively).

Van den Bold (1981) suggested a deep water environment of deposition for the lower part of the formation, based on Ostracod assemblages. Similarly, he also suggested shallowing toward the upper part and indicated the presence of deeper water intercalations in the middle part of the sequence. Obviously the environment of deposition of middle part of the formation remained deep and was intermittently invaded by shallower-water turbidites.

The Arc Formation, including the Bassin Zim limestones, crops out essentially along the northeastern edge of Plateau Central in Haiti.

MADAME JOIE FORMATION: Woodring, 1922, p. 6, 7. Named after the village of Madame Joie on the southern edge of Plateau Central (Figure 12).

Type locality: Morne Madame Joie, an isolated foothill ridge about 1 kilometer south of the village of Madame Joie.

At the type locality and elsewhere along the southwestern edge of Plateau Central, the formation is made up of a lower part, which consists of buish gray silstone, and an upper part of interbedded light yellowish tan coralliferous limestones, yellowish brown marly silstones, light yellow marls, and calcareous sandstones. (Figure 11) Total thickness at the type section is 60 meters (Woodring et al., 1924, p. 163).

The lower 30 meters of buish gray siltone described by Woodring et al., (op. cit) contains Pteropods of the genera Cavolina and Stylodictia, and Pelecypods of the genera Bathyarca and Limopsis, indicative of a relatively deep and clear water for the environment of deposition of this lithofacies (Woodring, 1922). The coralliferous limestones in the upper part of the sequence are characterized by the presence of large heads of Orbicella canalis and Orbicella altissima (Woodring et al., 1924).

The initial assignment of Early Miocene age has been corroborated by most subsequent workers (Hunerman 1972; Van den Bold, 1974, 1981) and my own study of samples referable to this formation along the southern edge of Plateau Central. As I have found in these samples, the presence of Globigerinoides trilobus, Gs. immaturus in the bluish gray marl would limit the base of the formation to about middle Early Miocene (Globigerinoides trilobus Zone). Nevertheless, the possibility of a latest Oligocene age for the base of the formation may not be totally ruled out, as I have also found planktonic foraminifera such as Globorotaloides suteri, Globorotalia opima and Glogorotalia aff. kugleri in a blue marl of the Madame Joie type of lithofacies southwest of Hinche (Figure 12) along the lower valley of Riviere

Abrio. Butterlin (1954, p.428) also suggested an upper Oligocene age for the Madame Joie Formation on the basis of the presence of *Amphisorus americanus*.

The Madame Joie Formation crops out along the southern edges of Plateau Central and in the southeastern areas of the Artibonite valley and the Mirebalais Basin. Its total thickness, as determined from drilling results, may exceed 700 meters.

THOMONDE FORMATION: Jones, 1918, p.736. Named after the village of Thomonde, in southeastern Plateau Central (Figure 12).

Type locality: Subsequently designated by Woodring et al., 1924, as being " in the vicinity of Thomonde".

The Thomonde Formation (Thomonde beds of Jones, 1918), consists almost entirely of fine grained sediments, chiefly bluish, soft shale (Jones, 1918, p.736). Woodring (1922), further added that near the top it includes a few thin beds of conglomerates. He also described the Thomonde Formation along the northeast side of Plateau Central to consist principally of nonmarine conglomerates and coarse sandstones, and considered the Maissade beds of Jones (1918, p.739) which consist of silstone, clay, carbonaceous clay, and lignite to form the upper part of the Thomonde Formation. Woodring et al. (1924, p.165) further pointed out that, at the type locality, the siltstone is similar to silstone in the lower part of the Madame Joie Formation (cf. preceding paragraph).

Woodring (1922) described the base of the Thomonde Formation to conformably overlie the Madame Joie Formation, and also indicated that it apparently overlaps the latter completely along the northeast edge of Plateau Central. Nonetheless, because these rocks assigned then to the Madame Joie Formation have been considered in the preceding discussions as the bassin Zim limestones, part of the Arc Formation, the Thomonde Formation instead overlaps the Arc Formation in the northeastern areas of Plateau Central (Figure 11).

The upper part of the Thomonde Formation intergrades with the Las Cahobas Formation (see succeeding paragraphs), from which it is often difficult to defferentiate.

The total estimated thickness of the Thomonde Formation is between 600 and 700 meters as determined by geologists of the Atlantic Refining Company (Van den Bold, 1981), but at the designated type locality it is only about 400 meters thick (Woodring, 1922).

In recent studies the age of the Thomonde Formation has been determined to be predominately Middle Miocene in the Plateau Central (Hunerman, 1972; Van den Bold, 1974). It is thus a little younger than the Early Miocene age assigned by previous workers. Similar, but not totally equivalent, facies which occur in the Saint Marc area have also been labelled the Thomonde Formation. In this area the rocks are Late Miocene to earliest Pliocene, as I have determined from samples collected at Bois Neuf (south of Saint Marc) and near the Arco drilling site (north of Saint Marc). The youngest samples include a diversified planktonic foraminiferal assemblage with Globorotalia margaritae, Globigerinoides extremus, Gs. obliquus, Globigerina pachyderma, and Globorotalia pseudomiocenica.

The Thomonde Formation crops out over a wide area in North Central Haiti, notably along the southern edges of Plateau Central, the Artibonite Valley, and the northeastern foothills of the mountains of Matheux, and near Saint Marc.

LAS CAHOBAS FORMATION: (Las Cahobes beds) Jones, 1918, p. 737; emended, Woodring, 1922, p 6, 9. Named after the village of Las Cahobas in southeastern Plateau Central (Figure 12).

Type locality: Subsequent designation, Woodring et al., 1924, as being "north of Las Cahobas".

The Las Cahobas Formation consists of coarser and more consolidated rocks than the detrital facies of the Thomonde Formation. (Figure 11). In general "it may be described as an alternating series of conglomerates, which are quite hard, with pebbles usually smaller than a robin's egg; sandy shales; some beds of coarse unconsolidated sands; thin beds of very hard sandstone with characteristically weather out to flat rounded knobs; some limy beds, and at some places coral limestones" Jones, 1918.

Also characteristic of the series are several beds composed mostly of Ostrea cahobasensis.

The coarser detrital facies distinct from the Thomonde, facies, are particularly well developed along the western and southern edges of the basin. "As these rocks are harder than the Thomonde rocks they form ridges with steep mountain-facing cuestas. Such a ridge formed by the basal rocks of the Las Cahobas Formation is a striking feature along the southern edge of the plain" (Woodring et al., 1924). At the type locality, north of Las Cahobas, there is a coralliferous limestone at the base of the formation containing among other biogenic remains heads of Orbicella imperatoris, Orbicella cavernosa, branches of Stylophora monticulosa, and Pocillopora cressoramosa. This limestone is also part of the rimrock mentioned above. According to Woodring (1922), along the northeastern sides of Plateau Central the Las Cahobas Formation is indistinguishable from the Thomonde Formation, as both consist principally of coarse detrital sediments and are included in the thick wedge of delta and flood plain deposits that taper southwestward. Although there are no coralliferous limestones at the base of the Las Cahobas Formation in these predominately clastic facies, the conglomerates include some molluscan shells indicative of a marine environment of deposition.

As pointed out earlier, the lower boundary of the Las Cahobas Formation is often elusive and intergrades with the Thomonde Formation. The upper part of the Las Cahobas Formation is unconformably overlain by the Hinche Formation

(Jones, 1918). Its maximum thickness is estimated to be as much as 1400 to 1850 meters (Arco drilling results).

The age of the lithofacies attributable to the Las Cahobas Formation in the Plateau Central may range from late Early Miocene, to possibly Early Pliocene. The greatest problem in assigning an age to clastic deposits of this sort is the lack of fossils. This explains the considerable discrepancy in age usually assigned to this formation, as reported in the relevant literature. As it appears, with the information available to date, the Las Cahobas Formation intergrades with most other formations in Plateau Central. The shallow deltaic to fan, and flood plain types of facies, which characterize this formation, may in fact include the whole Neogene series in this basin. Also, it seems that the bulk of the Las Cahobas facies developed mostly within the Middle and Late Miocene times. The Las Cahobas Formation could be perhaps best identified with the presence of oyster beds containing Ostrea Cahobasensis and Ostrea bolus, as reported by previous authors. The gastropod Orthaulax aguadillensis was initially believed to be a good marker to differentiate the Thomonde Formation where it was supposed to occur exclusively (Woodring, 1922; Woodring et al., 1924), but Butterlin (1954) pointed out that the above named gastropod can also be found associated with, or intercalated with, typical fauna assigned to the Las Cahobas Formation. Furthermore, the oldest beds of the formation are also reported to overlie the Arc Formation(Van den Bold, 1974), which may in fact be equivalent to those of the Thomonde Formation, as previously discussed.

According to Van den Bold (1981) the youngest beds of this formation in the Plateau Central area are found along the southeastern edges, and are reported to include an Ostracod fauna with Radimella confragosa and Cyprideis salebrosa, which may indicate an age as young as Late Pliocene. He also mentioned the presence of Globorotalia margaritae, which would confirm the Pliocene age.

In the Saint Marc area, the Pliocene series were assigned to the Las Cahobas Formation, while the older rocks were attributed to the Thomonde Formation. The age of these rocks were discussed in the preceding paragraph. It should be further emphasized that these facies are not the exact analogs of those found in the Plateau Central area. The different outcrops north and south of Saint Marc have yielded planktonic foraminiferal assemblages indicative of ages ranging from the early Late Miocene Globorotalia menardii Zone, north of Bois Neuf (6 kilometers south of Saint Marc), to the late Pliocene Globorotalia tosaensis Zone, near the top of Morne Rousseau, about 5 kilometers south of Saint Marc. These facies near Saint Marc will be kept with these formations until further studies.

The Las Cahobas Formation proper is the most widely spread lithofacies in the Plateau Central area of North Central Haiti.

MAISSADE FORMATION: (Maissade beds) Jones, 1918, p.739.
Named after the town of Maissade in
Plateau Central (Figure 12).

Type locality: Not designated specifically, but Jones (1918) cited areas north and west of Maissade along the Riviere Canot and its several tributaries, notably Riviere Fond Gras, Rio Piedre, and Rio Blanco (Riviere Blanche), where the Maissade beds are well exposed.

The Maissade Formation "consists of shales, marls and some sandstones, and is characterized by lignitic beds" (Figure 11), 1918. From the details of the section described along Rio Blanco by Jones (1918), the Maissade Formation includes a lower 9 meters or so of fossiliferous blue clay with molluscs (Turitella, Arca, Ostrea), and an upper part which consists of about 12 meters of interbedded black carbonaceous shales, hard shaly sandstones, lignites, lignitic gray clays, gray sandy shales, gray argillaceous marls, and blue clays. Most layers are characteristically rich in shallow-marine to lagoonal gastropod shells.

Woodring (1922) and Woodring et al., (1924), made a more detailed study of the lignite bearing series cropping out in the areas of southern Plateau Central around Maissade and southwest of Hinche. They concluded that "the lignite bearing rocks consist of a remarkable alternation of beds containing a marine fauna, mixed marine and brackish-water faunas, and a brackish water fauna. The brackish water fauna which is found immediately above or below the bed of lignite, consist principally of the molluscan genera Potamides, Hemisinus, Hydrobia, Nerita, Scapharca, and Mytylopsis. The marine molluscan fauna is confined to the lower part of the lignite bearing rocks. These marine molluscs are characteristic of the middle faunal Zone of the Thomonde Formation at its type locality, thus clearly showing that the Maissade beds represent a coastal-swamp facies of the middle and upper parts of the Thomonde Formation".

Although the lignite-bearing series were assigned to the Thomonde Formation, Woodring et al., 1924, p. 201, also pointed out the uncertainty concerning the real stratigraphic position of these beds. They reported that the marine beds of the "Maissade tongue" comprise molluscan fauna which are instead very similar to the molluscs found in the Las Cahobas Formation.

Most subsequent workers either included the Maisade facies in the Las Cahobas Formation or did not mention it at all. Van den Bold,(1974) reported that the "Maissade Formation was not mapped as such by geologists of Atlantic Refining Co. However, in their reports they often indicated "Beds with Maissade facies" (lignites and brackish-water faunas). Samples wih this type of fauna are present irregularly over the whole region and, except for the Maissade area, these beds cannot be mapped as a continuous unit" (p.537).

I may conclude from my own study of the area that both Woodring et al., (1924) and geologists of the Atlantic Refining Company made accurate observations concerning the dilemma of the exact position and viability of these beds as a separate lithologic entity. In fact, whereas lignitic beds occur intercalated in lithofacies attributable to the Las Cahobas Formation in the Maissade area, southeast of this area they appear in lithofacies referrable to both the Cahobas and the Thomonde Formation. Thus, the real

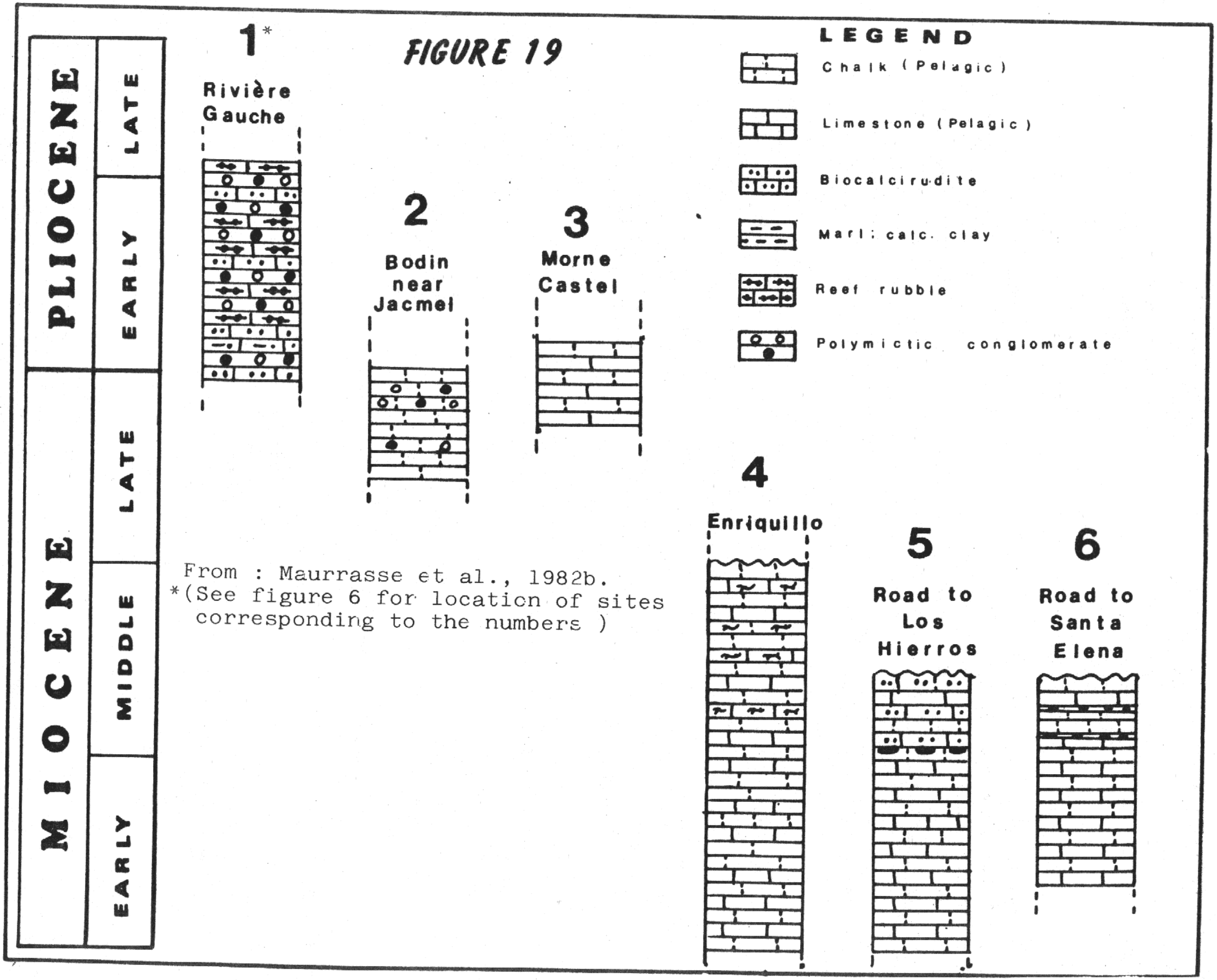


FIGURE 19

From : Maurrasse et al., 1982b.
*(See figure 6 for location of sites corresponding to the numbers)

problem lies in the fact that the lignite bearing beds are lateral facies which are time transgressive within the Central Plateau series (Figure 11). It is indeed difficult to map such a facies, because it is not at all continuous at any given outcrop. This is due to the fact that contrary to previous assumptions the lignitic beds did not develop over a swamp, but were rather carried sporadically by flood stages of the paleorivers of the area, probably from the old islands formed by the Montagnes Noires to the south and the Massif du Nord to the north. These lignitic beds are allochtonous deposits of plant debris which accumulated in marine channels and irregularities of very shallow estuarine environments. Thus their distribution in time and space within the Miocene series is as unpredictable as their composition. Their occurrence is known mainly within the Maissade area (Figure 12), where they are most typical and well developed, and along the southwestern edge of the Plateau Central basin.

HINCHE FORMATION: (Hinche beds) Jones, 1918, p.348. Named after the city of Hinche in the middle area of Plateau Central(Figure 12).

Type locality: Not designated.

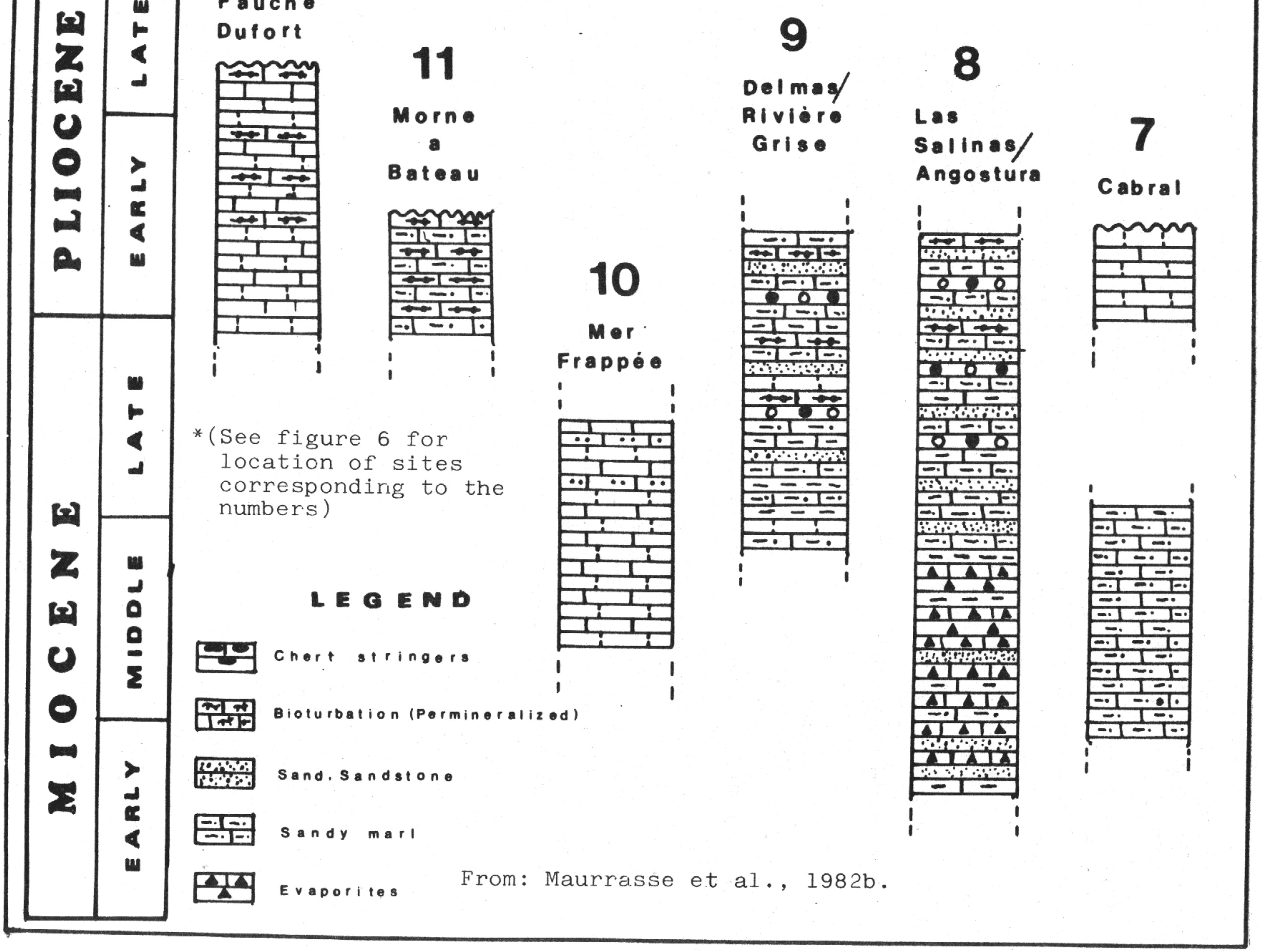
The Hinche Formation consists of a series of polygenic gravels and cross-bedded sands with occasional silts and clays. The predominance of limestone pebbles in this formation may be a criterion to separate this series from the Las Cahobas detrital lithofacies from which it can be difficult to differentiate. Although fossils are practically absent in these deposits, Jones (1918) reported the presence of fragments of petrified wood or even whole trunks of trees in the Hinche Formation. Both, its upper and lower limits are quite vague as it may intergrade with the Las Cahobas facies and more recent pebble deposits (Figure 11).

Its thickness varies from areas to areas in the Plateau Central, Woodring (1922) estimated its thickness to be about 25 meters, while Butterlin (1954) reported thicknesses up to 100 meters, based on drilling results of the Atlantic Refining Company.

These detrital deposits are widespread in the Plateau Central region where they are better developed in the southern areas. Jones (1918) inferred that the region, after uplift and folding, drained to the southeast toward the San Juan Valley and Azua Plain (Figure 2). The facies of the Hinche Formation would have been deposited over erosional surfaces which were flooded under a lake when the drainage system was cut off. He further suggested that the floor of the lake is represented by the uppermost Hinche beds, which remained practically intact in the northern part of the present Plateau Central, but are largely eroded in the soutern part.

RIVIERE GRISE FORMATION: Butterlin, 1950, p.56. Named after Riviere Grise, also known as Riviere du Cul-de-Sac, which flows in the Cul-de-Sac Plain (Figures 8,12).

FIGURE 20



From: Maurrasse et al., 1982b.

Type locality: Subsequent designation, Butterlin, 1954. Trail Bassin General, Morne Jacquot. Habitation Cadet, Goujon, on a south facing slope, south of Habitation Cadet, at an altitude of 500 meters (Butterlin, 1960, p.46).

The Riviere Grise Formation consists of alternating layers of polygenic conglomerates with basaltic, limestone and chert pebbles, brown or yellow sandstones, brown limestones, marls and gray or bluish claystones, generally in thin beds (Figure 11). The upper part of the series is generally richer in clastic components than its lower part. The various levels of the formation contain abundant marine biogenic remains, particularly benthic foraminifera, notably Sorites americanus; madreporaria, gastropods, pteropods, pelecypods and scaphodods. A bed rich in Ostrea haitensis also occurs in the series on the road from Fond Parisian to Fond Verrettes, and at an altitude of about 400 meters.

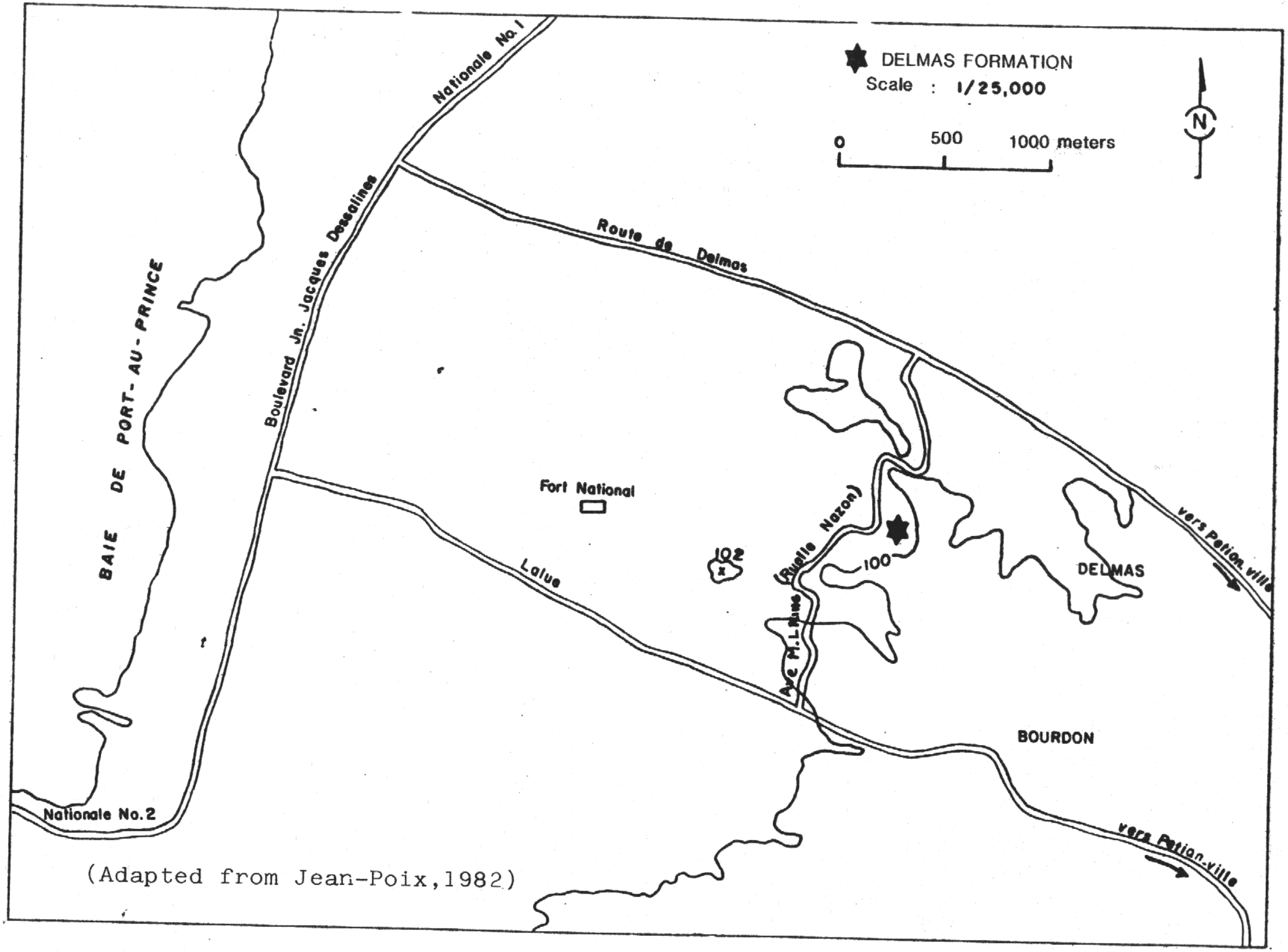
Originally Butterlin (1950; 1954) considered these series to be Oligo-Miocene, but subsequently (1960) indicated that they may be Miocene, possibly lower Miocene, based on the presence of the benthic foraminifera Sorites americanus. The samples I analyzed from these series have so far yielded a planktonic foraminiferal fauna indicative of a late Middle Miocene age or younger (Figures 20 and 11).

Butterlin (1950; 1954; 1960) suggested a total thickness of at least 1000 meters for the Riviere Grise Formation. He also reported outcrops of this formation in most of the northern foothills of the La Selle Mountain along the southern edge of the Cul-de-Sac Plain, namely along the valleys of Riviere Grise, Riviere Blanche (Figure 6), and at the confluence of Riviere Grise and La Voulte. He further noted that rocks of similar facies are found in the valley of Riviere Grande Anse, near Jérémie, in low hills in the Plaine des Cayes, in the depression which is associated with the Trans-Xaragua fault system transecting the Southern Peninsula diagonally (Figure 3).

MORNE DELMAS FORMATION: Butterlin, 1950, P.56. Named after Morne Delmas, in Port-au-Prince (Figure 12, 21).

Type locality: Subsequent designation, Butterlin, 1954, p 65. Trail of Ruelle Nazon (presently Avenue Martin Luther King) 500 meters south of Morne Delmas (Figure 21).

The Morne Delmas Formation consists of conglomerates, sands, sandstones, coarse argillites with occasional limestone beds rich in Ostrea haitensis, and numerous other molluscan shell fragments associated with coral fragments (Butterlin, 1960). The bottom of the formation is reported to unconformably overlie the River Grise Formation, and is similarly overlain by Quaternary alluvium.



(Adapted from Jean-Poix,1982)

FIGURE 21 : Map showing location of the type locality of the Delmas Formation in the city of Port-au-Prince.

Butterlin (1960) assigned a Middle to Late Miocene age to the Delmas Formation on the basis of faunal similarity with the Bowden Formation in Jamaica. Van den Bold (1974) assigned the formation a Pliocene age, which is in agreement with my study of samples from these deposits. I also believe that Morne Delmas Formation is similar to the upper part of the Riviere Grise lithologic series (Figure 11). It is also worth noting that Woodring et al., (1924) did not differentiate these series which they refer to as the "Beds near Port-au-Prince". Perhaps such an appellation best described these series as a whole unit.

Butterlin (1960) gave an estimated thickness of 300 to 400 meters for the Morne Delmas Formation, which he pointed out occur between Port-aPrince and Petionville, the road of Delmas, between Port-au-Prince and Frères (northeast of Petionville). He also considered the detrital series east of the town of Gressier and those near Carrefour Fauche (Figure 12) as belonging in this formation.

Lithofacies of the western portion of the southern edges of the Cul-de-Sac/Enriquillo Neogene seaway, as described for the Riviere Grise and Delmas Formations, are much similar to those found in the eastern areas of the Dominican Republic side of the graben, except that they lack the evaporites. These facies best termed "Beds near Port-au-Prince (Woodring et al., 1924; Coryell and Rivero, 1940) are characterized by extreme vertical and lateral lithologic changes. Like their eastern counterpart, the terrigenous components consist of clastics elements similar to those being carried by rivers of the present drainage system (Figure 6). Thus, the existence of these rivers as main sources of terrigenous supplies is documented since at least the Miocene. The provenance of the clastics also implies that the present mountain range of the La Selle-Baoruco Block stood fairly high since that time. Late Quaternary uplift may have only accentuated the preexisting relief.

Fine volcanogenic debris also occur in variable amount among the clastics within most of the formations, particularly within the levels corresponding to the latest Miocene. These volcanic products were evidently carried across the graben from the volcanoes north of the basin, as Neogene volcanoes occur only in this part of the island. The spread of these volcanic products is indeed, compatible with expected distribution pattern controlled by the Trade winds of that time.

The oldest foraminiferal assemblages from the Riviere Grise lithofacies yielded foraminiferal taxa indicative of the Late Miocene Globoratalia siakensis Zone. Low diversity observed in these assemblages indicate stressed conditions of a neritic environment close to the shelf edge. The younger planktonic foraminiferal assemblages found in facies attributable to the Delmas Formation belong in the Middle Pliocene Globorotalia altispira Zone, and possibly the Globorotalia tosaensis Zone. The younger facies are also more neritic, suggesting gradual shallowing related to the combined effects of progradation and accentuated uplift toward the close of the Miocene and the Early Pliocene, to total emmersion during late Pleistocene. Conditions were such that the sediments were laid in a basin in which fans along the margins graded into deeper-water neritic environments, away from the deltas (Figure

19). Thus, upper bathyal to nerito-pelagic and hemipelagic facies intertongue with coarser components as a result of both intermittent subaqeous mud flows during flood stages of the adjacent rivers, and basin edge mud slumps associated with tectonic instability of the active boundary fault system, and further volcanic activities to the north.

RIVIERE GAUCHE FORMATION: Butterlin, 1954, p.67; 111. Named after Rivière Gauche, one of the tributaries of the Rivière de Jacmel, which flows southward within the Jacmel-Fauché depression (Figure 2).

Type locality: Subsequent designation, Butterlin, 1960. On road Trouin - Jacmel, 12.8 kilometers southeast of Trouin (Figure 12).

The Rivière Gauche Formation is defined to include conglomerates, yellow or brown sands, and coarse brown argillites. The bottom of the formation is reported to unconformably overlie older Miocene rocks, and its top is overlain by Quaternary allubium, or coral reefs(Butterlin, 1960, p.47).

The thickness of the formation has been estimated by Butterlin (op. cit.) to be within the order of 250 meters. The Riviere Gauche Formation is supposed to characterize the sedimentary deposits of the Jacmel-Fauché depression. It is found in the valley of Riviere Gauche, and Riviere Lavagne, (or Rio Fauche) flowing south and north respectively, within the depression.

ELEVATED TERRACES

Raised terraces are well developed throughout the Caribbean region, and in Hispaniola in particular. The most spectacular terraces occur in the Northwestern Peninsula in Haiti, and the Beata Peninsula at the extreme eastern end of the La Selle-Baoruco block in the Barahona Province of the Dominican Republic.

The highest terraces in Haiti reach an altitude greater than 500 meters in the Northwestern Peninsula at the Bombardopolis Plateau (Figure 4), and the highest ones in the Dominican Republic are those in the Barahona Province cresting at more than 1200 meters. Terraces in this latter area are covered with significant amount of ore grade laterites which are presently mined for Bauxite. Laterites also occur on the Bombardopolis Plateau but their relatively high silica content (Si 02 = 21%) indicates a rather poor grade Bauxite.

Pleistocene terraces of the Northwestern Peninsula, such as those near Mole Saint Nicolas (Figure 5), are also found in numerous areas of the island, but they are never as well developed. The best preserved ones worth mentioning are those found at Cap Saint Marc south of the Bay of Saint Marc, the northwestern end of the Southern Peninsula near Roseaux east of the city of Jérémie (Figure 4, 10), west of the city of Jacmel, along the southern coast of the Southern Peninsula in Haiti, and at the Llanura costera del Caribe (Figure 2) at the southeastern end of the Central Cordillera physiographic unit (cf. section on physiographic provinces).

The terraces of the island have not yet been studied as extensively as those of other Caribbean islands where similar raised reef terraces occur, as for instance the well known and well-studied Barbados terraces. As pointed out earlier, the island is seismically active and much tectonic activity has taken place in the Late Pleistocene, but not much is known about the rate of vertical displacement during that time. A recent study in the Mole Saint Nicolas areas has brought some direct evidence of fast uplift in the region. Dating of the lower series of terraces in this area shows that the most prominent terrace cresting at 52 meters gives Th_{230} / U_{234} dates on unrecrystallized Acropora palmata which average 126,000 yrs ± 5000 yrs B.P. Assuming a sea level of 6 meters above present level (as it has been reported in the literature) at 125,000 years ago, the date gives an uplift rate of 37 cm. per 1000 yrs. Such a rate makes the Northwestern Peninsula of Haiti, the site of fastest reported uplift in the Caribbean (Dodge et al., 1981). Fast uplift in the northern regions is in sharp contrast to nearly negligible uplift rate recorded in the southeastern regions of the island. The difference has been attributed to crustal tilting from each other side of the Cayman trench (Horsfield, 1977).

ROAD LOG TO EXCURSIONS

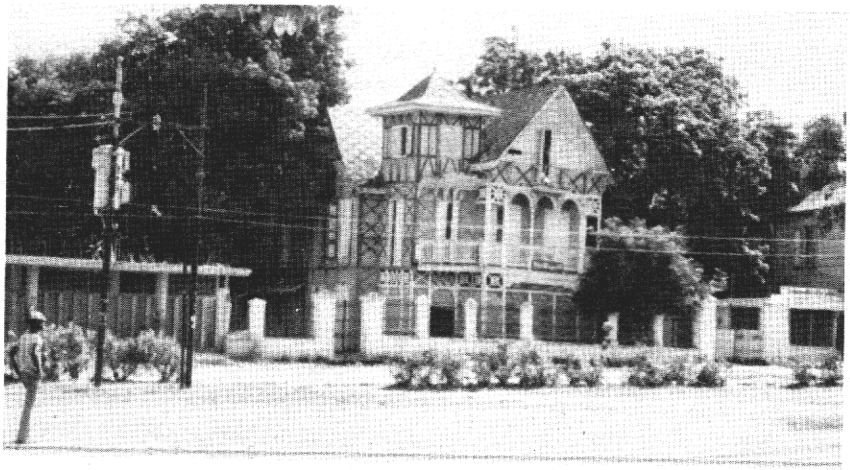
EXCURSION ONE: PORT-AU-PRINCE - JACMEL

The city of Port-au-Prince is built over conglomeratic series of the Riviere Grise/Delmas Formations which became emergent during the Pleistocene. As you can see from figure 3, the city is built along the edge of one of the major fault systems which mark the southern boundary of the Cul-de-Sac/Enriquillo graben.

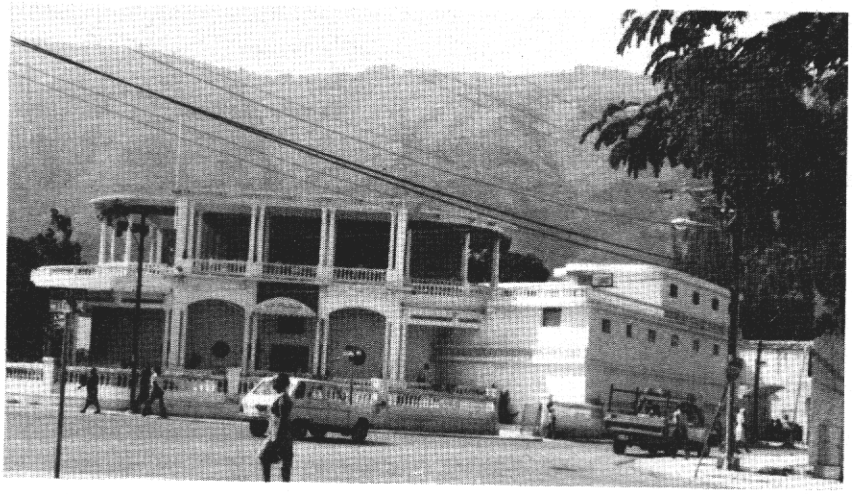
Most of the bedrock is Miocene or Pliocene, as discussed in the section on the formations. The nature of the bedrock here has provided excellent physical conditions for the rapid expansion of the city. The clastic deposits are indeed easy to excavate and exhibit high porosity and permeability. Such properties are particularly advantageous as the entire city uses only septic tanks and privies. The presence of easily accessible calcareous breccia along the fault zone has also been a major determining factor in the rapid expansion of Port-au-Prince. The most recent architectural style attests to this change, stone and concrete structures are rapidly replacing the old Victorian style gingerbread houses (Figure 22). The calcareous breccia or Laboule sand (Maurrasse and Pierre-Louis, 1982), occurs in great abundance throughout the foothills of the La Selle Mountain which forms the backdrop of the city.

The center of the city from the main square down to the bay is built on fanglomerates of a huge holocene fan developed at the mouth of several dry channels, and particularly the one called Ravine Bois de Chene. This fan slopes gently (Figure 22c) toward the bay where its delta is still transgressing quite rapidly. It has transgressed more than 200 meters during the past 25 years. The sedimentary processes presently taking place in this

FIGURE 22



Gingerbread victorian house, Port-au-Prince.



Concrete and cement block structure, Port-au-Prince.

Gently slopping topography typical of the distal zone of the alluvial fans which constitute the substratum of downtown Port-au-Prince. Photo taken near the national Palace looking west toward the bay.

bay are excellent analogs of those which gave rise to the detrital sequences known as the Riviere Grise/Delmas Formations, as previously mentioned.

As we proceed westward toward Carrefour, the western suburb of Port-au-Prince, you will notice on the left side of the road, steep talus fans which are still transgressing over the upper Neogene series. These fans have developed and are still developing along the edge of the Morne l'Hopital horst (the mountain in the immediate backdrop of the city). Accelerated growth of these fans during the late Pleistocene is related to renewed uplift in the area at that time. Like the larger fan over which most of down town Port-au-Prince is built on, these steeper fans were also formed by rapid deposition from dry channels which may be transformed into raging floods of muddy water carrying a heavy load of coarse rock-fragments from the upland region during the rainy season.

Because most of the geologic outcrops in this coastal region are hidden by urbanization, the logging of observable features will start from the bridge crossing Riviere Froide at Carrefour. In figure 23 you may notice the small promontory associated with the transgressive delta of Riviere Froide. The alluvial plain formed by this delta is very visible from plane view as one approaches Port-au-Prince for landing. This delta is about 5 kilometers wide, and slopes gently to the shore from an altitude of 30 meters at the bridge.

0 Km. Bridge crossing Riviere Froide on Nationale 1.

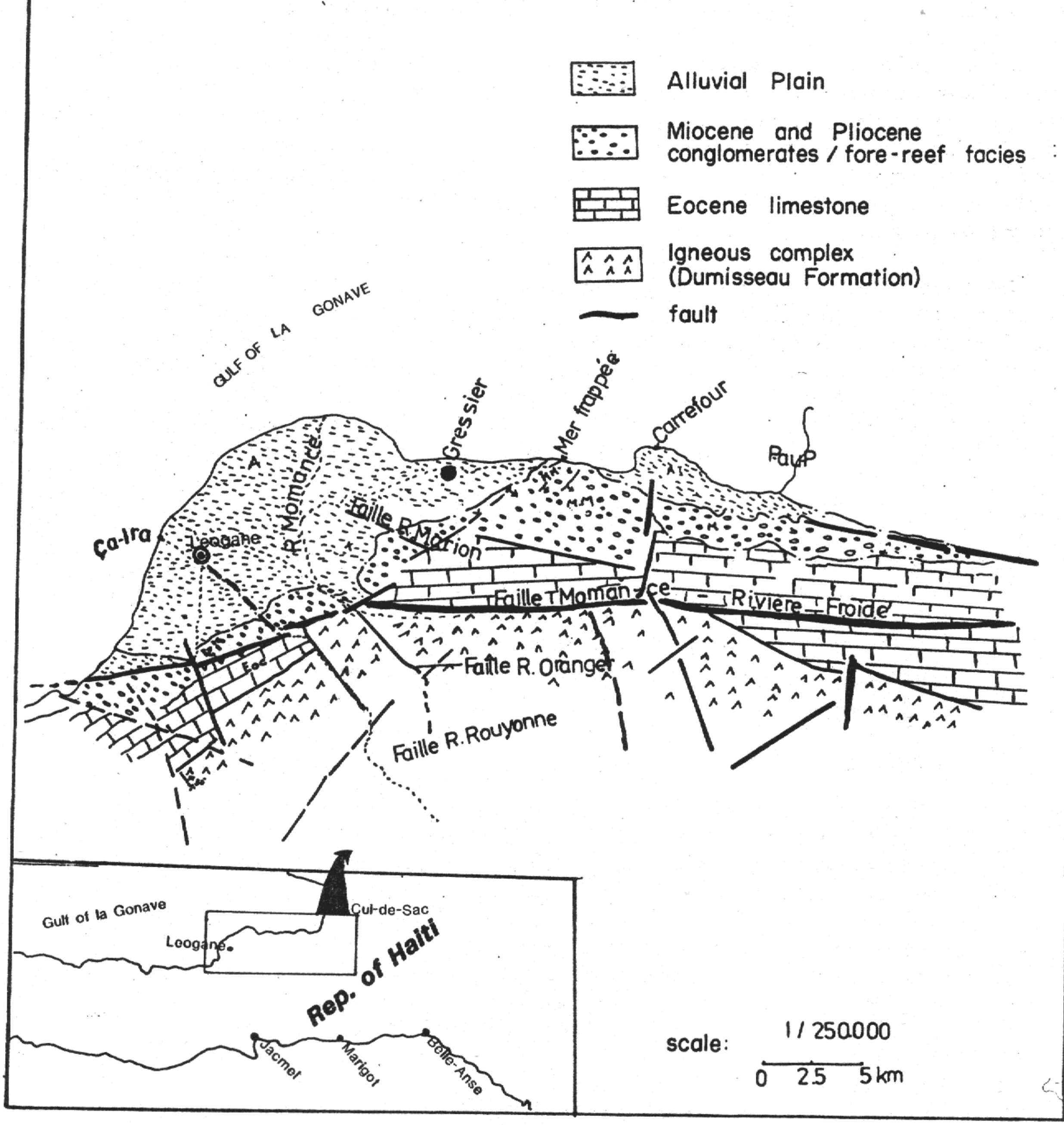
1.76 Km Left side of road, slope wash conglomerate at crossing of railroad.

3.7 Km Outcrop of thinnly bedded limestone and chalk at the locality called Mer Frappee and similar to section shown in figure 20.

4.5 Km STOP 1 : Le Lambi

From this area westward there are good exposures of pelagic limestones and chalks of middle to late Miocene age. The rocks are essentially partly indurated foraminiferal biocalcilutite. At this locality the exposure is about 75 meters thick and is fractured. The lower part of the sequence yielded a rich planktonic foraminiferal fauna of the middle Miocene *Globorotalia mayeri* Zone, including a few reworked Oligocene taxa. The youngest levels indicate a late Miocene age, possibly in the *Globorotalia acostaensis* Zone. The predominance of planctonic foraminifera up to the middle portion of the sequence indicates eupelagic conditions until the end of the middle Miocene. Conditions seem to have changed significantly within the late Miocene when the foraminiferal assemblages become enriched in benthonic foraminifera. Benthonic organisms, including some ostracods, and echinoid debris, become gradually predominant toward the upper part of the series. The absence of coral fragments, however, indicates that shallowing was not adequate over this site

FIGURE 23 – Plaine de Leogane and adjacent areas



to allow coral growth. The depths were still nerito-pelagic, away from any terrigenous influence as well. Because there is a rapid change in depth recorded in this area within the late Miocene, whereas other areas within the La Selle-Baoruco block remained essentially pelagic at that time, it is clear that this larger tectonic unit comprises smaller sub-blocks which behaved differentially through time.
Lithofacies found in this stop are comparable to the Neiba type of facies. They also grade into facies comparable to the Florentino Formation (Bermudez, 1949) in the Dominican Republic.

4.8 Km — Recurrence of the limestones seen previously. Here they are capped with modern slope wash.

4.9 Km — Chalky conglomerate.

10.0 Km — STOP 2 : Morne à Bateau

This locality is only about 5.5 Km away from the preceding stop but here the facies are distinctly different. It is the continuation of the shallowing trend observed before. However, hère sedimentation was also influenced by terrigenous input, most likely from the paleo-Momance River. Like for localities farther east and west, terrigenous supplies were sporadic, and only the distal part of turbidites reached this area. As pointed out by Woodring et al., 1924, here the sequence consists of alternating beds of dark yellowish sand and clay, and calcareous conglomerate which is composed of lumpy aggregates of coral and mollusk fragments. Benthonic foraminifera and well diversified ostracod fauna may also predominate at certain levels. A few bryozoan and echinoid fragments also occur among the coarse components.
Beds composed of finer constituents include diverse planktonic foraminiferal assemblages, but most of the specimens are remarkably small. The planktonic foraminifera indicate an age ranging from the latest Miocene *Globorotalia dutertrei* Zone to the early Pliocene *Globoquadrina altispira* Zone. A few reworked Eocene and Oligocene taxa also occur in the series.

It is apparent that the sequence at this locality accumulated on or near a slope in a neritopelagic environment which was intermittently affected by terrigenous and bioclastic subaqueous flows. The basin edge was characterized by prolific coral growths, probably fringing reefs developing along the edge of a steep and narrow margin. The coastal area was apparently a high energy environment , as suggests the highly fragmented state of the benthonic foraminifera and the other benthic

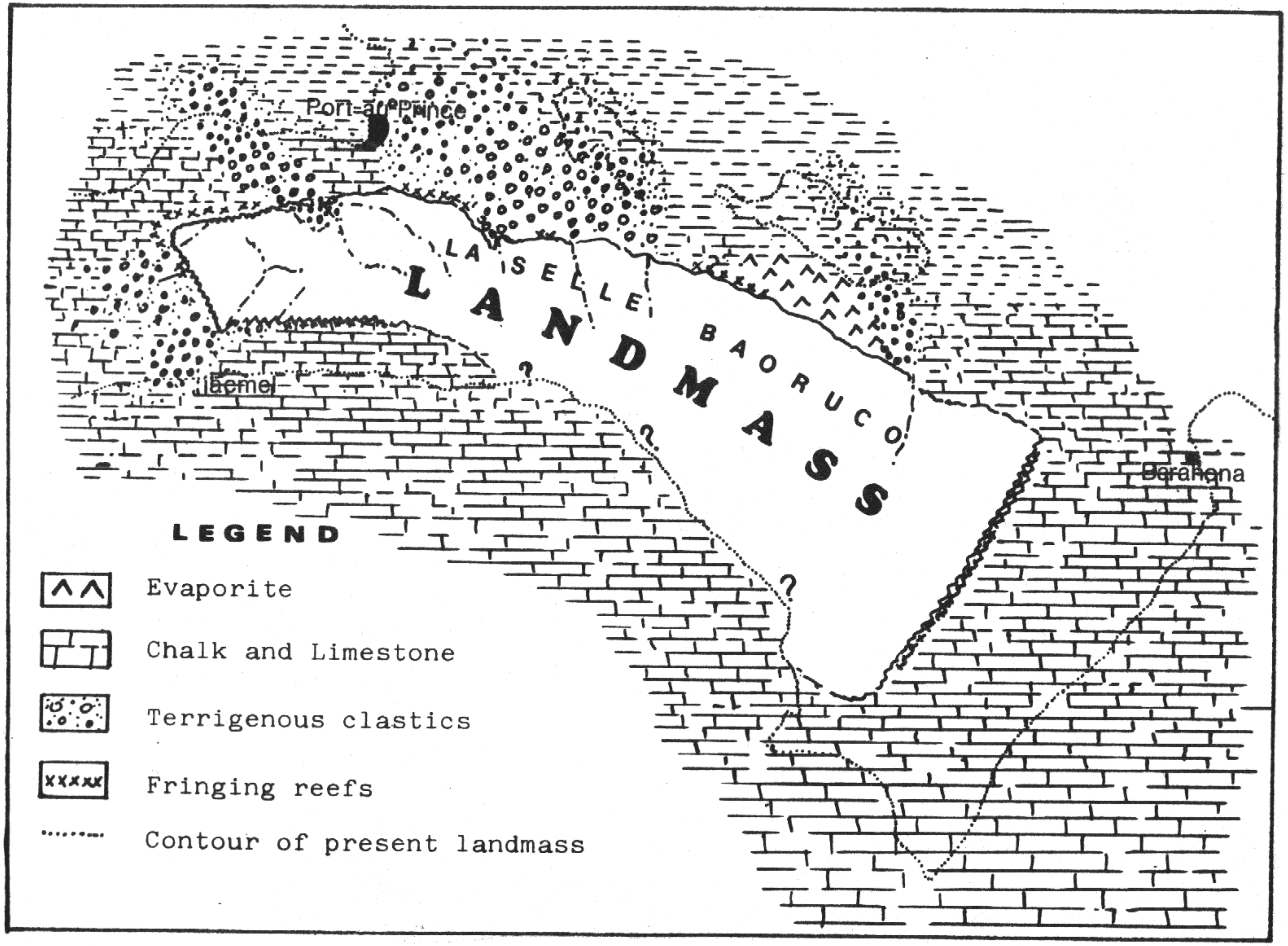


FIGURE 24 : Paleogeography and lithofacies distribution around the La Selle-Baoruco block during Middle and Late Miocene. (After Maurrasse et al., 1982b)

components. A paleogeographic reconstruction for the time of deposition of these facies is given in figure 24.

13.0 Km — Gressier. This small town is located at the eastern rim of the Leogane Plain. Small hills in this area are of the same facies as at stop 2.
We proceed into the Plain of Léogane. As can be seen in figure 23, this plain is the result of prograding sediments deposited by three deltas related to Riviere Cormier at the western end of the plain, Riviere Rouyonne in about the center, and Riviere Momance at the eastern edge. The effects of the Momance River has been predominant and the plain grew asymmetrically toward the delta of this river (figure 22).

19. 7 Km — Crossing of the bridge on River Momance. Note braided nature of the river caused by excess load due to accelerated erosion in the deforested upland areas.

24. 1 Km — Entrance of the city of Léogane, which lies to the right in about the center of the plain. This city is the site of the Pre-Columbian Arrawak city of Yaguana, now distorted and called Léogane since colonial times. Yaguana was the capital city of the Xaragua, which was governed by queen Anacaona when Colombus arrived in the island.

31. 2 Km — Crossing of bridge on Riviere Cormier, immediately north of the junction with the road going to Jacmel toward the left.

Road post 43 Km from Jacmel, south of Carrefour Dufort.

END OF ROAD LOGGING BASED ON BRIDGE CROSSING RIVIERE FROIDE ON NATIONALE ONE.

NEW LOGGING USES DISTANCES AWAY FROM JUNCTION ROAD TO JACMEL AND NATIONALE 1

0.5-1.0 Km — <u>STOP 3</u> : Foothill, immediately south of Carrefour Dufort.

This section is similar to outcrops near Fauché farther west (Figure 20), or about 3 kms west of Fauché. Both areas include a relatively well developed sequence of bedded neritopelagic limestone and chalk reminiscent of the facies found along the eastern end of the La Selle-Baoruco block, in the Dominican Republic (Figure 1) (Maurrasse et al., 1982b). In both areas the limestones comprise large amounts of coral fragments within the younger series, as shown in the composite sections of figures 19 and 20.

The limestone layers consist of packed foraminiferal biomicrite, including about 5 to 50 percent benthonic foraminifera. Ostracods are also relatively common, although they do not exceed 1 percent of the coarse fraction greater than 44 microns. Echinoid and coral fragments are virtually absent in the older portion of the sequence, becoming abundant at certain levels in this outcrop. Planktonic foraminifera indicate an age ranging from the latest Miocene *Globorotalia dutertrei* Zone, to the Late Pliocene *Globorotalia tosaensis* Zone.

This sequence indicates that neritopelagic conditions prevailed at this site at least until the early Pliocene. The Pliocene portion shows that extensive fringing reefs must have also developed at that time. Numerous layers of reef rubble in the fore reef zone further indicate a high energy environment of deposition, or storm deposits. The youngest levels including coral rubbles contain large fragments of *Acropora Palmata*, indicating the development of fringing reefs similar to modern reefs in the present offshore area adjacent to these localities.

This area became emergent either during the latest Pliocene or the Pleistocene. In the present topography the Neogene rocks crop out at a maximum elevation of about 75 meters above sea level

From here on the road climbs rather steeply into the backbone of the Southern Peninsula. Two or three kilometers uphill you will already be able to observe igneous rocks of the Dumisseau complex. We are also crossing a very disturbed area which is the westernmost end of the Momance-Riviere Froide Fault system (Figure 8, 23)

2.0 Km STOP 4 : LABOULE SAND QUARRY

(near road post 41 Kilometers from Jacmel)
Here the Momance - Riviere Froide fault transects the mountain flank and gave rise to limestone breccia called the "Laboule Sand", after the name of the locality of Laboule south of Port-au-Prince where it was first quarried.
You may also observe an outcrop of Campanian foraminiferal- nannoplankton chalk overlying deeply weathered igneous rock of the Dumisseau complex. The nonconformity shows a very short transitional zone including fragments of the underlying igneous rock, and shallow-water organisms. The chalk contains a rich planktonic foraminiferal fauna, and

a fairly large number of euhedral clear spinel crystals. Farther up the road (about 1.6 kilometers from here) the chalk facies changes into thinly bedded limestones and chalks which yield a foraminiferal assemblage of the Trinetella scotti Zone, or Late Maastrichtian age. Modern analogs of such chalks are found in the eupelagic marine environment of the Caribbean Sea at depths of 2000 meters or more. Thus, here there is clear evidence that eupelagic environments lasted through the latest Cretaceous, as will be seen further in subsequent stops. This implies that tectonic disturbance in the area took place prior to the Maastrichtian

As we proceed upward along the steep slope look toward the right and contemplate the magnificent drop off related to the scarp of the Trans-Xaragua fault system which transects exactly along this area.

3.00 Km. Fault breccia developed in the more brittle shallow-water limestones of Tertiary age. Note the extensive karst features which developed in the fractured limestones.

4.10 Km. (Location near road post 39 Kilometers of Jacmel). Columnar basalts occur in the dry valley on the right side of the road. From here onwards to Beloc there will be extensive outcrops of the Dumisseau complex, as can be seen for instance between 12.5 and 13.00 kilometers (figure 9). There, the Coniacian limestones are completely dislocated, becoming independent blocks mixed within the equally dislocated igneous rocks (see also paragraph on Dumisseau Formation).

14.4 Km. STOP 5

Large outcrop of steeply dipping to vertical Coniacian limestone. A thin doleritic sill also occurs parallel to the bedding plane of the limestone layers.

16.2 Km. A major northeast-southwest trending fault cuts across this area. Slightly farther you may see spheroidal weathering of the igneous rocks. Also observe a thick medium coarse volcanogenic conglomerate believed to be the distal equivalent of the coarser basal conglomerate reported at the type section of the Beloc Formation. Minor hydrothermal mineralisation of manganese also occurs in this area.

17.5 Km. Here the Dumisseau Formation is uncorformably overlain by middle Maastrichtian chalk and limestone (Figure 25) intercalated with intrabasinal volcanogenic turbidites with a chalky matrix which contain abundant reworked Campanian fauna (Globotruncana carinata, Globotruncana elevata, and others). The contact between the Maastrichtian chalk and the volcanogenic turbidite also shows minor

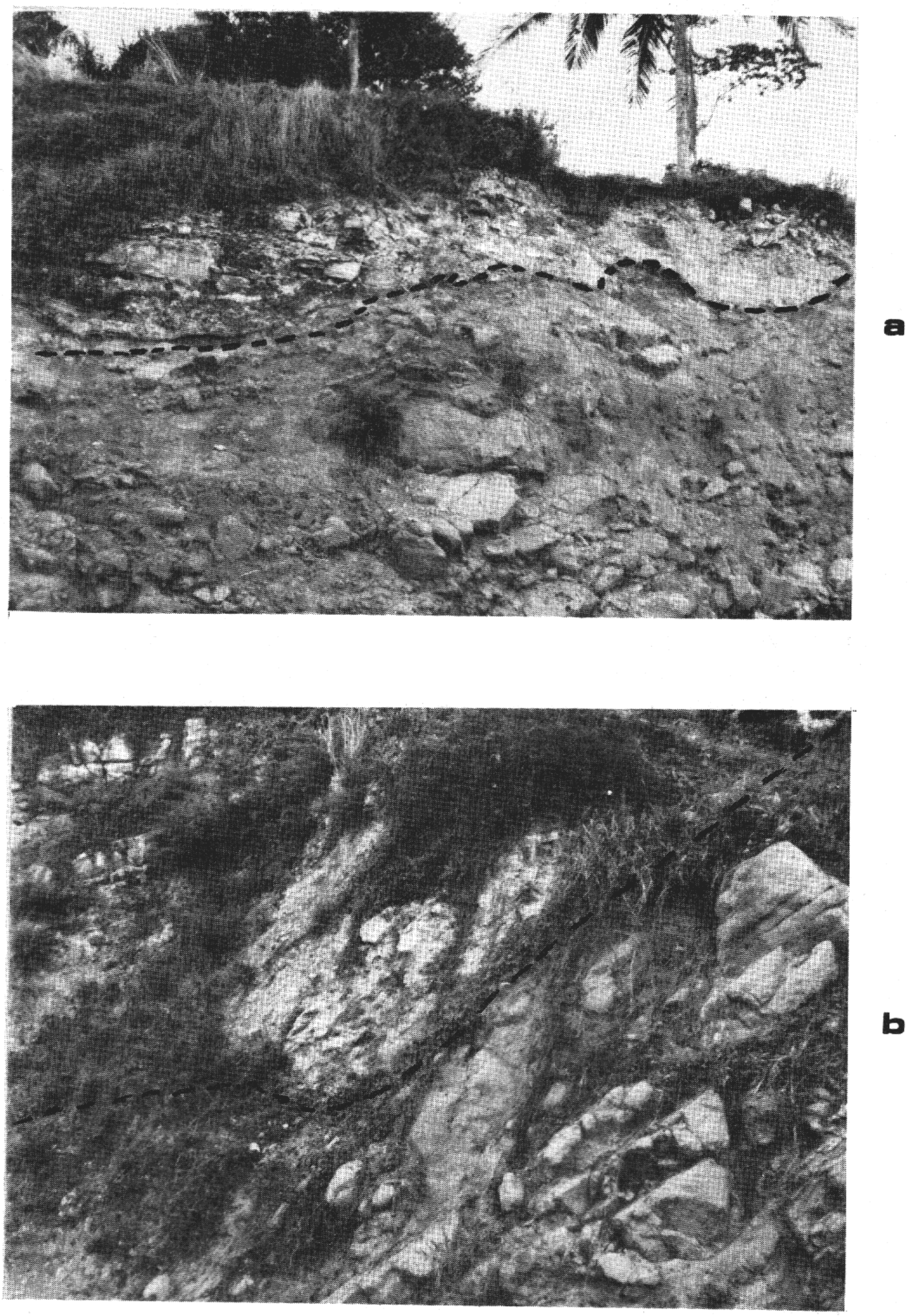


FIGURE 25 : Angular unconformity between medial Maastrichtian limestone and chalk, and the Dumisseau complex near Béloc, Southern Peninsula of Haiti(STOP 6).

hydrothermal alteration with manganese oxides as the prevalent minerals. Manganese is pervasive in the chalk but does not form a crust as it usually occurs in deep-sea environments where such concentration is often associated with bottom currents and periods of non-deposition. Hydrothermal activities in this area were most likely related to fissure eruptions during the early stages of the Trans-Xaragua fault system which may have been activated during the pre-Campanian or early Campanian tectonic disturbance previously mentioned. As seen at stop 4, the chalk here is also rich in planktonic foraminifera, and includes numerous clear spinel crystals, and probably Galaxite (Manganese aluminum spinel) as well.

17.7 Km. STOP 6

Outcrop of the above described uncorformity, which is shown in figure 25. Here the medial Maastrichtian series is unconformably overlain by early Tertiary shallow-water limestone without a basal conglomerate. This implies the development of bank, but not a total emergence. As indicated before, the early to Middle Eocene age of the shallow-water limestones and a continuous pelagic limestone sequence spanning the Cretaceous/Tertiary boundary give evidence only for a post Maastrichtian tectonic disturbance in the area. This tectonic event shows no record of the emergence of a land mass, nor does it show extensive shallowing throughout the Southern Peninsula. Only scattered banks appear to have been formed at that time.

18.5 Km. Village of Beloc. Note the calcareous breccia on the right side of the road where it is capped with lateritic soil. This type of calcareous breccia, or "Laboule sand" developed here along a northeast-south- west trending subsidiary fault.

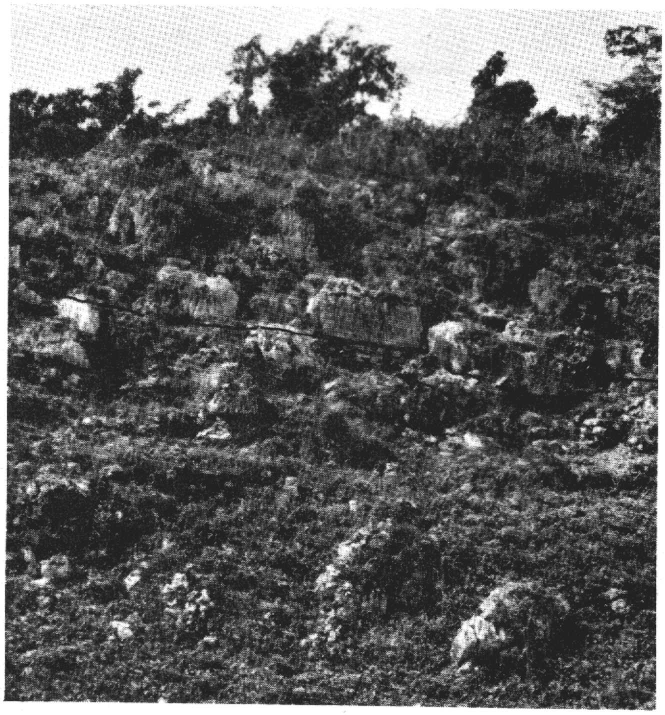
19.5 Km. STOP 7

Outcrop of the Beloc Formation, immediately south of the hamlet of that name. The marker bed is much contorted and dislocated by multiple faults which transect the Formation throughout. Farther southward south-dipping gravity faults can be seen all along the road cut showing extensive outcrops of the Béloc Formation (figure 15), which occurs over more than five kilometers southward from the town of Beloc.

22.0 Km. STOP 8

Beloc Formation close to the standard section. Here the sequence is not folded it is affected only by minor displacements along gravity faults. The basal conglomerate which occurs in the Formation, crops out along the River valley, some 75 meters down from the road. The marker bed occurs about two-thirds the way up along the steep slope of the river valley at this location.

FIGURE 26



a

Shallow-water limestone conformably overlying deep-water chalk and limestone. Arrow points to narrow transitional zone. Near Découzé, Southern Peninsula of Haiti.

b

Karst developed in shallow-water limestone of Middle Eocene age. Near Découzé, Southern Peninsula of Haiti.

24.1 Km. Limit between "Departement de l'Ouest and Departement du Sud'Est" is also a fault controlled natural boundary: Note volcanoclastic basaltic conglomerate immediately south of the sign, on the left side of the road.

This fault here also marks the limit of the standard section of the Beloc Formation. To the left of here (i.e. toward the east) the section continues in the hills above. The summit of the amountain includes shallow-water limestones containing abundant benthonic foraminifera and common coral fragments. Those limestones are of Middle Eocene age.

As I pointed out before, since the Paleocene is continuous with the latest Cretaceous in the Beloc section, it is clear that here actual shallowing took place sometime within the Early Paleogene, and not at the end of the Cretaceous, Maastrichtian stage. Furthermore, as can be seen farther south of here, only part of the La Selle/Baoruco block became partially emergent, forming isolated banks at that time. The lower hills toward Jacmel indeed exhibit successively younger eupelagic limestones facies southward, the youngest series are of Pliocene, implying differential emersion of the block throughout the Cenozoic.

25.2 - 26.0 Km. Découzé. Note the deep lateritic soil which developed over the igneous basement complex of the Dumisseau Formation. Note also occurence of calcareous breccia of the Laboule sand type, which always characterizes fault zones affecting the shallow-water limestone facies.

26.1 Km Immediately south of Découzé. Here lower Oligocene (<u>Globigerina ampliapertura</u> Zone) of the Neiba type of lithofacies rapidly changes upward into shallow-water facies (Figure 26). The foraminiferal biocalcarenite immediately above the deep water chalk, shows a fabric indicative of a subaqueous flow process. Shallowing of this area may have either brought the bottom of this site close to wave base or a current system was influential over the bank. Benthic foraminifera (<u>Lepidocyclina</u>) also suggest an Oligocene age for the calcarenite.

Shallowing may have been very rapid as the thinnly bedded eupelagic chalk is separated from the overlying biocalcarenite by less than 15 cm of transitional lithology (figure 26A). This Oligocene shallowing event thus bring further evidence of punctuated uplift as the main tectonic characteristic of the area.

27.0 km. Occurrence of chalk facies of the Jérémie Formation.

28.8 km. Fault contact between the younger pelagic facies to the south and the older Middle Paleogene biocalcarenite and biocalcirudite to the north. The biocalcirudite here contains distinct coral fragments and abundant calcareous algae, both indicative of a water depth of less than 50 meters for the bottom of the bank at this location.

31.8 km. Nerito-pelagic Limestone of latest Miocene to possibly earliest Pliocene age, Morne Castel section (figure 19). Note magnificent gravity thrust and folds in these limestones and chalks. These southwest dipping thrust faults evidently developed as a result of differential uplift of the area during latest Cenozoic.

32. km STOP 9 MORNE CASTEL

Neogene rocks occur up to an altitude of about 480 meters in this area. The rocks consist of thinnly bedded foraminiferal-nannoplankton chalk, and packed foraminiferal biocalcarenite. The planktonic foraminiferal assemblages are well diversified and include taxa indicative of ages ranging from the late Miocene to the early Pliocene, Globorotalia margaritae Zone (including *Globorotalia margaritae*, *Globoquadrina altispira*, *Globigerina bolli*, *Globorotalia siakensis*, *Gl. miocenica*, *Globigerinoides extremus* etc.

This facies developed in a pelagic environment beyond the reach of terrigenous influences from the existing emergent La Selle-Baoruco block (figure 24). This lithofacies is much the same as limestones cropping out near the town of Enriquillo at the extreme southeastern end of the La Selle Baoruco block. It can also be compared to upper Miocene limestones found along the western edge of the Matheux Mountain range (Stop 12).

Note the numerous NE-SW trending faults which transect the mountain as the road proceeds downhill toward the valley of Grande Riviere de Jacmel.

33.8 km. Voluminous slope wash fanglomerate developed in fault zone which separates the Oligocene series from the Miocene rocks mentioned in preceeding stop. Note that the younger Miocene rocks in fact overstep this slightly down dropped portion of the La Selle-Baoruco block.

35.1 km. STOP 10 Eupelagic facies of the Jérémie Formation. The foraminiferal fauna is well preserved and includes taxa such as *Globorotalia nana*, *Globoquadrina venezuelana*, *Globigerina ampliapertura*, *Globigerina opima*, *Globigerina angulisuturalis*, indicative of early to Mid-Oligocene age.

Downhill the road crosses again disturbed medial Miocene limestones which underlie the conglomeratic deposits occurring at the foothills along the edges of the river valley.

35.4 to 36.1 km. Shallow-water limestones (biocalcirudite and calcarenite) unconformably overlie thinnly bedded yellowish marl of Middle-Miocene age. Note again the intensity of breceiation in the more competent shallow-water facies as compared to a consistently more ductile deformation exhibited by the thinnly bedded pelagic chalk. Fringing reefs apparently developed on the fractured nerito pelagic marl.

FIGURE 27

a

b

Polygenic conglomerate in flood plain deposit along eastern bank of Grande Rivière de Jacmel, Southern Peninsula of Haiti

39.0 km. Outcrops of tan yellowish brown chalk of Middle-Miocene age (includes Globorotalia fohsi and Globorotalia mayeri).

This nerito-pelagic facies is overlain by a shallower-water conglomeratic series containing some coral heads. The latter deposit is in turn overlain by flood plain conglomerate (figure 7) of the paleo-Grande Rivière de Jacmel, probably deposited during Pleistocene higher sea stand. The fluvial deposits are characterized by their lack of fossils and the presence of primary sedimentary structures related to a varying flow intensity and pattern. The calcareous conglomerate here has its deeper-water equivalent northeast of Jacmel, at the low hills of Bodin, along the west bank of Grande Rivière. Outcrops of polygenic conglomerates at that location show well preserved chalky matrix very rich in planktonic foraminifera. The species include Globorotalia pseudomiocenica, Gl. plesiotumida, Gl. acostaensis, Gl. aff. humerosa, Globigerina nepenthes, Globigerina haitiensis, Sphaeroidinella subdehiscens, Sphaeroidenellopsis seminulina etc., indicative of a Late Miocene age. The abundance of the planktonic species is in sharp contrast to the scarcity of the benthonic species. This suggests a bathypelagic environment of deposition which was intermittently disturbed by terrigenous sediments from nearby rivers in flood. The steepness of the basin edge, plus dilution of surface water by rivers apparently prevented the growth of fringing reefs at this location. The present analog of such environments can be found along the eastern end of the La-Selle-Baoruco block where the Enriquillo-Cienaga-Paraiso fault (figure 3) cuts along the coast.

41.5 km. Locadi - Road cut displays a superb erosional channel filled with coarse polygenic conglomerate, in sharp contrast to the sparse and finer grained conglomerate, sandstone and marl underneath.

42.0 km. Thick flood plain deposits (figure 27). Note the size of some of the boulders which may be larger than 150 cm in diameter. The conglomerates include abundant limestone and basaltic pebbles characteristic of rocks from the nearby hinterland. Some layers, however, show predominance of basaltic pebbles, indicating fluctuations in the supply of the clastics. The variations were controlled by either differential weathering, or asynchronous flood stages of the mountain streams which are influenced by the orographic effects on the local rain system, as can be observed in present day conditions.

43.0 km. Entrance of the city of Jacmel. The city is built partially on flood plain conglomerates, older Pleistocene clastics, and poorly defined raised reef terraces. In places coral heads make up more than 30 percent of the polygenic conglomerate. Of the two levels of the city, the hillsides are underlain by conglomerate deposited by the Rivière de Jacmel during a higher sea stand of the Pleistocene, and the lower part represents a narrow coastal alluvial plain built up during present sea stand. Note the nineteenth century charm still preserved in the numerous gingerbread buildings (figure 29).

EXCURSION TWO: JACMEL - PAILLANT

The Southern Peninsula is crossed once more to reach Carrefour Dufort.

HERE THE LOG IS BASED ON DISTANCE FROM CARREFOUR DUFORT, WHICH IS 37 KMS west of PORT-AU-PRINCE.

As we turn left to move westward along the northern side of the Southern Peninsula observe hills of Miocene - Pliocene limestones as discussed in Stop 3. Note disturbance in Middle Miocene rocks and faults scarp related to the prolongation of the Momance-Riviere Froide Fault in this area.

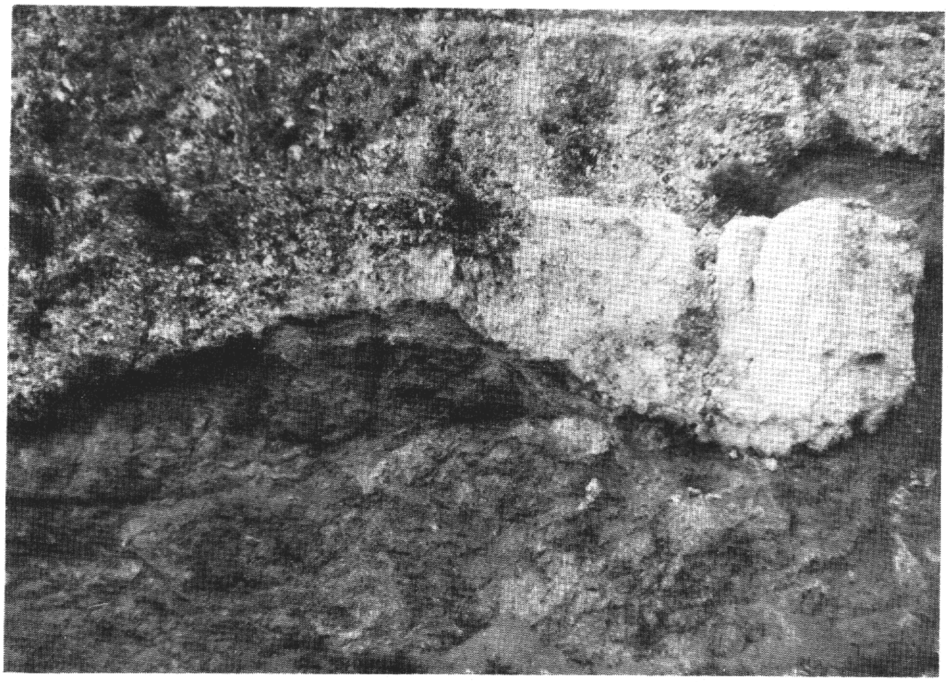
8.0 km. Crushed Miocene limestone and marl, much similar to the facies previously observed on the southern side of the Peninsula (see section of road log after Stop 10).

10.6 km. Carrefour Fauché. Northern extremity of the Jacmel Fauché depression. South of here, clastic deposits rich in coral fragments occur within the depression (figure 2-3). These rocks are part of the Rivière Gauche Formation (figure 19). Scarce planktonic foraminifera found in this lithofacies are not diagnostic of a very precise age, but suggest a late Miocene _Globorotalia menardii_ Zone for the oldest exposed rocks. The predominately coralline beds are remarkably rich in delicate branching taxa (_Porites_, and possibly _Acropora cervicornis_) in the younger levels. The absence of wave resistant forms such as _Acropora palmata_ at these levels may indicate an age older than latest Pliocene, for the top of the formation because the later species is not reported in the Caribbean until that time (Frost, 1972). This lithofacies was deposited in a marine channel that filled the trough of the Jacmel-Fauché depression until probably the latest Pliocene to Pleistocene. Intermittent tectonic disturbances along the fault-bounded trough appear to have caused sporadic slumps of huge quantities of reef rubble into the basin which was receiving large amount of clastics from the rivers and basin edge rock fall. These facies of the Riviere Gauche Formation are much reminiscent of the lithofacies of the Arroyo Blanco Formation (Bermudez) in the Azua Basin, near Fondo Negro, Dominican Republic.

13.0 km. "Tapion de Petit Goave" can be seen to the right, and in background are the mountains of Durissy toward the axis of the Peninsula, where rocks of the Dumisseau complex crop out extensively.

14.9 km. Entrance to the city of Grand Goâve, and bridge crossing river of same name.

FIGURE 28



a

Slope wash of limestone breccia filling erosional gully on Dumisseau complex, near Etang de Miragoane, Southern Peninsula of Haiti.

Andesitic agglomerate intercalated with eupelagic chalk of latest Middle Eocene age (possibly earliest Late Eocene, see text). Puilboreau Mountain, northern Haiti.

b

18.0 km. Foothills of the Tapion of Petit Goâve. The road follows the southwestern flank of this mountain which is a small horst bounded by northwestern striking faults. Note breccia all along the road which practically follows the strike of the southwestern fault.

18.8 km. Folded conglomerate.

21.0 km. View of the Bay of Petit Goâve.

23 - 24 km. Limestone breccia and fault scarp fanglomerate.

29.3 km. Entrance to the city of Petit Goâve. Dumisseau complex crops out on southside of road.

32.1 km. Brecciated shallow-water Eocene limestones. Brecciation here is related to the Trans-Xaragua fault system which crosses this area (figure 3) of the Peninsula diagonally.

32.3 km. Outcrop of the Dumisseau complex which is overlain by fault-scarp fanglomerate. Note nonconformity on south side of road.

35.0 km. Vialet depression, a minor pull-apart zone asociated with the Trans-Xaragua fault. A fault scarp can be seen on the north side of the road (limestone cliff to the right) transecting the mountain. This fault-bounded mountain stood as a nearly separate island during the Pleistocene when most of the present depression was part of a marine gulf which occupied most of the present low-land areas associated with the fault.

41.0 km. Limestone debris that filled erosional channels on the deeply weathered rocks of the Dumisseau complex (figure 28A).

41.9 km. Pillow basalt in Dummisseau complex.

46.5 km. Oliver. Intensely folded and faulted chert intercalated with basalt of the Dumisseau complex. Note fault scarp on northern side of road.

47.9 km. From this area westward view of the Etang de Miragoâne. Note limestones in igneous rock just before crossing bridge over outlet channel of the lake. An igneous intrusion also occurs near the road. It is related to later magmatic activities along the fault line.

At Carrefour Desruisseaux you observe cliffs with rugged topography which consist of Pleistocene reefs. They extend southwestward to Fond des Nègres. They are also found west of the city of Miragoâne about 2 kilometres north of Carrefour Desruisseaux.

The presence of the Pleistocene reefs around the Plateau de Rochelois and Massif du Bonnet Carré (figure 4) are evidence for the extension of the marine gulf over this area during the Pleistocene.

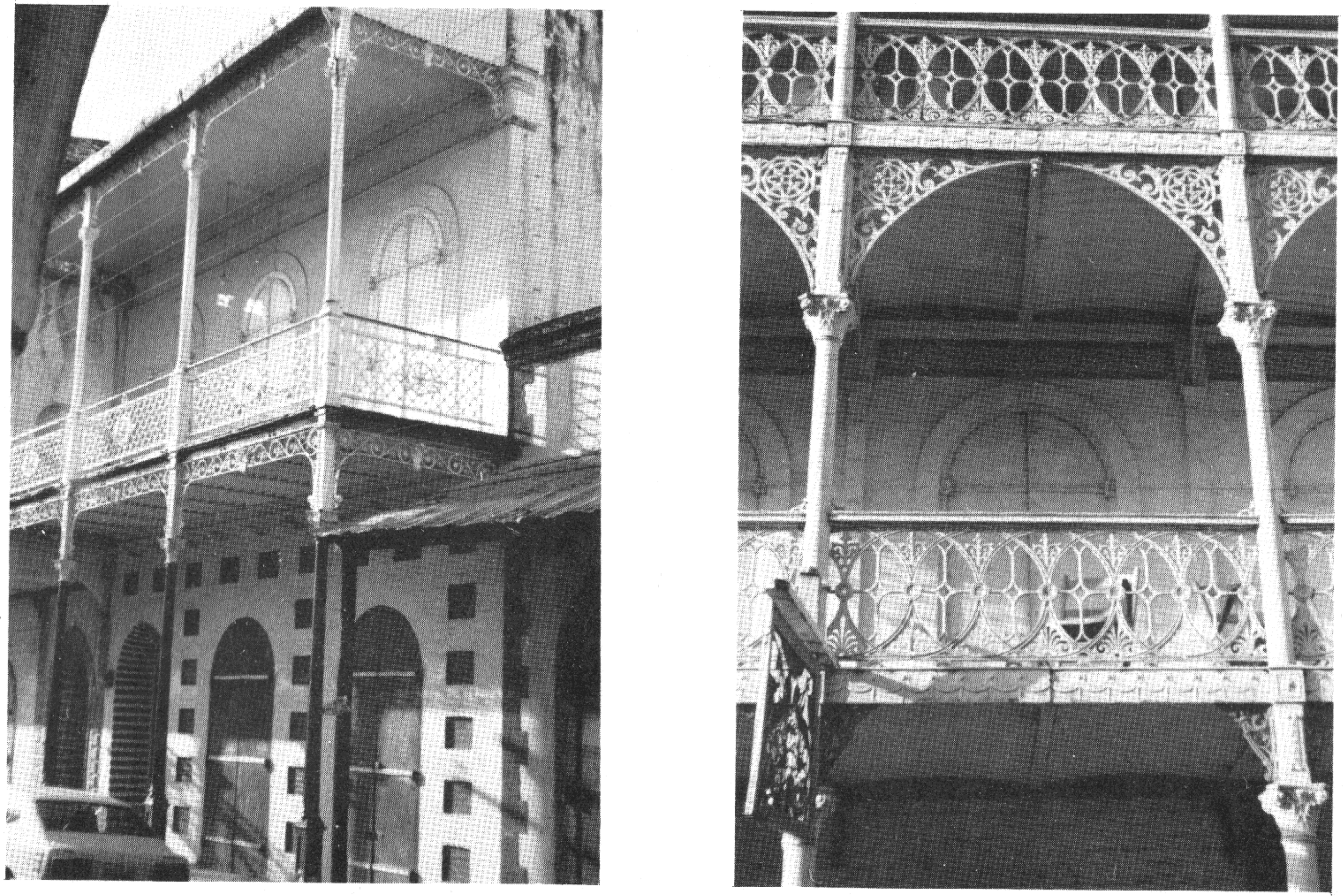


FIGURE 29 Examples of residential and commercial (ground level floor) houses adorned with fanciful ironwork balconies, built at the turn of the century. Jacmel, Southern Peninsula of Haiti.

Near Miragoane the reefs developed over a basement of the Dumisseau complex south and east of the city, whereas they overlie Oligocene to Miocene Pelagic limestone and chalk facies west of the city. Pillow basalts of the Dumisseau complex can also be observed on the west side of the road from Carrefour Desruisseaux to Miragoâne. Many outcrops of Oligocene chalk occur in windows underneath the reefs between Miragoâne and the loading facilities of the Reynolds Haitian Mines Company west of the city.

To the west of Carrefour Desruisseaux, on the road to Cayes, more outcrops of the Dumisseau Complex also include pillow basalts. Biohermal coralline limestones are well developed up to Fond-des-Nègres (Figure 12). It is probable that the marine gulf isolated the portion of the Southern Peninsula west of the Vallée de Fond-des-Nègres (figure 4) to Vieux-Bourg d' Aquin, from the eastern portion wich was then an extension of the island formed by the La Selle-Baoruco block.

After crossing the city of Miragoâne the road proceeds westward along the steep coast bordered by mangrove swamps. About a kilometer west of Miragoâne observe a large karst spring underneath the coralline limestones. The water from this spring is brackish (salinity is about 10.5 parts per thousand, Woodring et al., 1924) suggesting it comes also from the Oligocene chalk which is slightly salty in this area.

ROAD LOG IS HERE BASED ON DISTANCES FROM THE JUNCTION OF THE ROAD TO PAILLANT WITH THE MAIN ROAD. (BAUXITE DRYING AND LOADING FACILITIES OF THE REYNOLDS HAITIAN MINES).

1.2 km. Note extensive karst topography developed on the Pleistocene coralline limestones of raised reef terraces. Most of these coralline rocks are of the back-reef environment and unconformably overlie the Oligocene series.

2.9 km. Calcareous breccia related to dislocation along subsidiary faults of the Trans-Xaragua fault system (figure 3).

3.2 km. Thinnly bedded foraminiferal limestones and chalk of a facies analogous to the Neiba Formation in the Dominican Republic, as previously mentioned. Occasional chert stringers are present at scattered intervals. The series is remarkably rich in Chilogumbelina which are here of large size, as compared to the usually small size of this group exhibited elsewhere. These rocks are of Early Oligocene age, possibly latest Eocene in the lowest part of the section.

Farther up hill toward Paillant observe gradual change of the Neiba type of facies into the Jérémie Formation type of facies.

3.5 km. STOP 11. About 12 meter high cliff of very white chalk with intercalation of irregularly shaped coarse biocalcarenite lenses

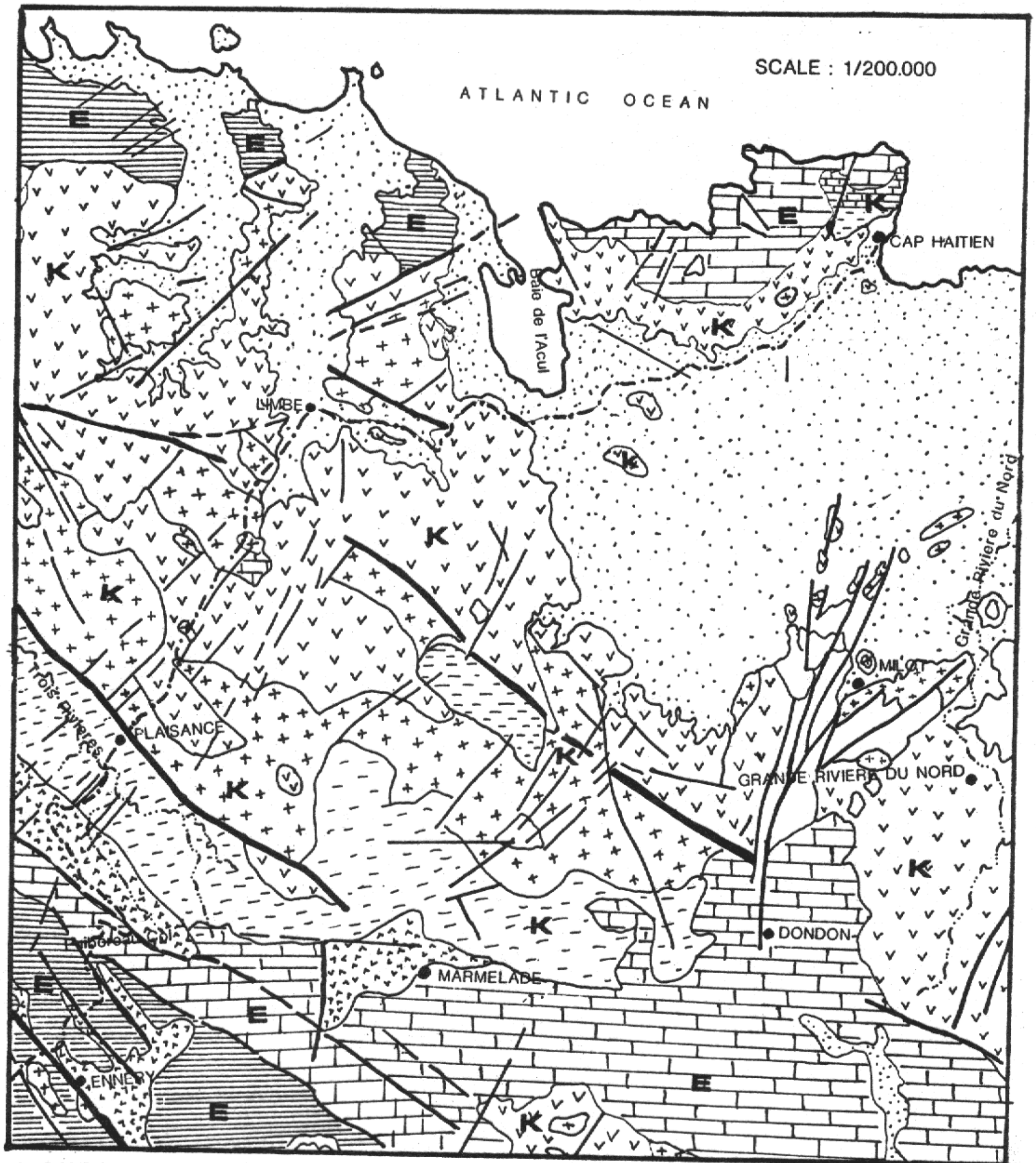


FIGURE 30 Geologic map of northern Haiti from Ennery to Cap Haitien (modified from U.N/D.M.R.E Provisional Geologic Map of Haiti)

K : Cretaceous E : Eocene

Main road — Rivers — Trois Rivieres Formation — Plaisance Formation Shallow-water limestone

Neiba/jeremie limestone and chalk facies — Igneous(basaltic)

Igneous(andesitic/rhyolitic) — Igneous(basaltic:Post-Cretaceous) — Alluvial and layers. This is again the Jérémie Formation type of facies. As mentioned in the discussion on the formations, here there are numerous coarse biogenic turbidites intercalated with the chalk. The chalk layers consist essentially of foraminiferal-nannaplankton biomicrites is dominated by the great abundance of Chilogumbelina. Other taxa include Globigerina rohri, Globorotalia opima, Globigerina ampliapertura and Globigerina aff. turgida, indicative of Middle Oligocene or earliest Late Oligocene age. The biocalcarenite layers include mostly shallow-water benthic foraminifera and associated neritic organisms.

The bioclastic layers are also often partly silicified, much in the same manner as will be observed in closely related but older facies at STOP 16. These intrabasinal biogenic turbidites evidently slumped into deep water from the edge of shallow bank with steep edge. Modern analogs can be examplified by present conditions prevailing over the Bahama bank area.

Large influx of neritic elements into the deep basin was partially controlled by changing dynamic conditions over the bank probably related to the reported world-wide sea level low during the late Oligocene (Vail et al., 1977).

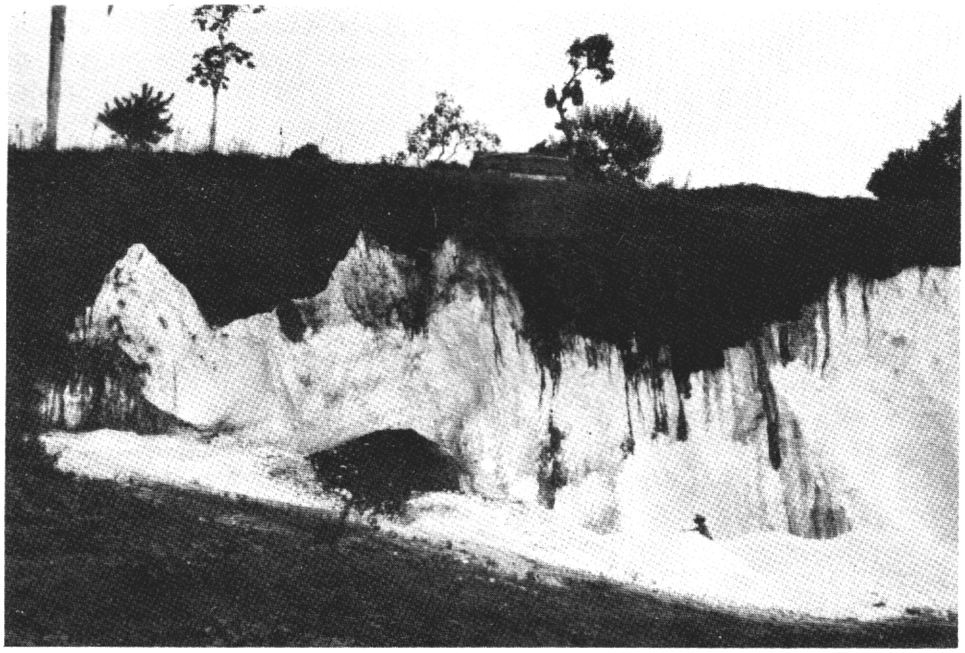
Note minor high angle transversal faults cutting the series as we proceed uphill toward Paillant located at the edge of the Plateau de Rochelois. This road climbs to an altitude of nearly a thousand meters in about 16 kilometers, which makes for one of the steepest haul grades in the world.

The bauxite mining area occurs immediately after the village of Paillant. Note sharp contrast between calcareous breccia and overlying Bauxitic soil all along roads crisscrossing the irregular surface of the Plateau (figure 31A). Pine forests grow over various reclaimed areas.

Like other bauxitic deposits in the Caribbean such as those in Jamaica and the Barahona Peninsula (figure 2) in the Dominican Republic, the bauxite of the Plateau de Rochelois occurs on a Karst terrane. In the Paillant area bauxite occurs as blanket and shallow pocket deposits of a few meters thick, and in places in deeper pockets 3 to 15 meters thick. The Reynolds Haitian Mines, a subsidiary of Reynolds Metals Co., is the sole mining company of the deposits. Mining started in 1956, and since shipments are processed at the company's alumina plant in Corpus Christi, Texas.

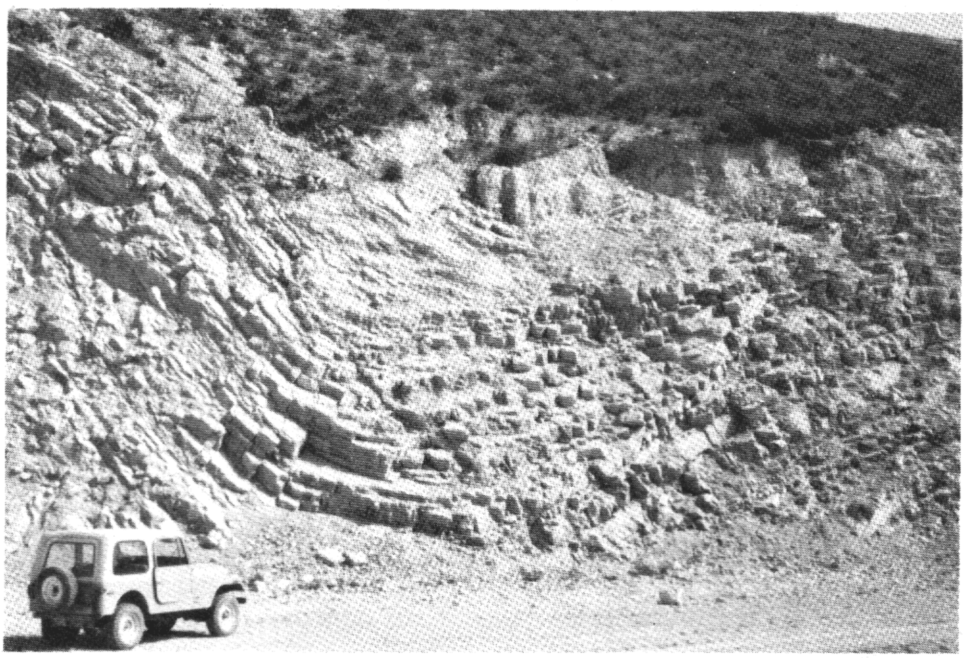
The bauxite here apparently derived from weathering of volcanogenic products and to a lesser extent from residues of the limestone substrate. Their predominately igneous origin is supported by several lignes of evidence: 1) high purity of the underlying limestones; 2) the bauxitic laterites always occur over the limestones without transition 3) their mainly gibbsite $Al(OH)_3$ composition.

FIGURE 31



a

Bauxite capping calcareous breccia. Plateau de Rochelois near Paillant, Southern Peninsula of Haiti.



b

Gently folded upper Miocene nerito-pelagic limestone at Source Matelas quarry, 30 kilometers north of Port-au-Prince, Haiti. (STOP 12)

The weathered igneous rocks at the origin of the bauxite may have derived in part from neighbouring rocks of the Dumisseau complex. It is also inferred that allochtonous ash products from volcanoes located north of the Cul-de-sac/Enriquillo graben may have provided the bulk of the parent material which accumulated over the area during Oligocene and Miocene times. The trade winds of these times may have been the primary factor controlling the distribution of the ashes over this area. Extensive laterites must have developed over the area as early as middle Miocene times because upper Miocene clastic deposits in the Peninsula also include red lateritic clays.

The average alumina (Al_2O_3) content of the bauxite of the Plateau de Rochelois is about 50 percent, silica (SiO_2) content is about 3.4 percent, and iron oxides 21 percent. Presently the bauxite of this Plateau is the only economic mineral being explored in Haiti. Other potentially exploitable deposits occur farther east in the La Selle Mountain (figures 3,4).

END OF EXCURSION 2 RETURN TO PORT-AU-PRINCE FOR OVERNIGHT STAY.

EXCURSION THREE: PORT-AU-PRINCE - CAP HAITIEN

ROAD LOG IS BASED ON DISTANCES GIVEN BY THE ROAD POSTS.

As we turn on Nationale one from the road adjacent to the international airport note yellowish-brown marl on the right side. This is part of the Delmas-Rivière Grise Formations which make up the hills of Port-au-Prince, as previously discussed.

We proceed across the fertile part of the southern edge of the Cul-de-Sac Plain, cross the bridge over Rivière Grise (also called Rivière du Cul-de-Sac) and continue northward. Note progressive change that takes place in the vegetation which becomes totally xerophytic in the northern part of the plain. This is due to the rain shadow effect of the Chaine des Matheux and Montagnes du Trou d'Eau (figure 4).

The Cul-de-Sac Plain is the western extension of the major pull-apart depression which divides Hispaniola into two distinct geologic provinces. The area was open marine during most of Cenozic time but became emergent during late Pleistocene due to a later episode of compression related to strike-slip motion along the northern Caribbean megashear (Maurrasse et al., 1982b). These late tectonic activities gave rise to high-angle reversed faults as well as minor thrust faults along both the northern and southern edges of the depression.

17.0 km. Pebbly mudstone of late Pleistocene to Holocene ages. Note low hills made up of fanglomerates which developed along the southwestern side of the Chaine des Matheux (Figures 3-4).

19.0 km. Crossing of the western end of the fault system at the northern boundary of the Cul-de-Sac Plain.

20.9 km. Thermal Spring called "Sources Puantes" on the west side of the road near the mangrove swamp. The water averages a temperature of 33°C; it is rich in hydrogen sulfide and dissolved minerals (salinity is about 12.7 parts per thousand: Woodring et al., 1924). Preliminary geothermal reconnaissance works have been undertaken in the area in order to assess its geothermal potentials. Across is a quarry of calcareous breccia which is used as building material, as previously mentioned. The road climbs the gentle slope of the alluvial fans developed along the scarp of the NW-SE trending fault of the Southwestern flank of the Chaine des Matheux. Coral heads are also found among the boulders.

26.0 km. Titanyin. Here the low hills are underlain by medial Miocene marl and limestone. These facies can be better observed north of this locality at an open pit quarry which can be seen at the distance.

30.3 km <u>STOP 12:</u> SOURCE MATELAS Figure 31B Quarry of the "Ciment d'Haiti" at Source Matelas is in late Miocene nerito-pelagic facies. The series shows gentle folding and minor faulting throughout. Biogenic content is a rich planktonic foraminiferal fauna including among other taxa, <u>Globigerinoides haitiensis</u>, <u>Gs. obliquus obliquus</u>, <u>Globorotalia pseudomiocenica</u>, <u>Globigerina nepenthes</u> etc. The facies indicates that the area remained under pelagic conditions even though it was adjacent to the emergent Matheux-Trou d'Eau land mass which has apparently remained an emergent block since at least the latest Oligocene. The prevailing paleogeographic conditions of this area during the Miocene are much reminiscent of those previously discussed for the La Selle-Baoruco block, i.e., an island surrounded by steep sided, fault controlled margins. Subsequent tectonic activities incorporated this island into the larger Hispaniolan land mass. Steep, fault-controlled margins still occur farther north of here, near Montrouis. The nerito-pelagic facies here are similar to those found at the periphery of the La-Salle-Baoruco block (Maurrasse et al, 1982b).

From Duvalierville northward the low hill topography and the gently dipping Plaine de l'Archahale are also the results of talus fan deposits along the edge of the western boundary fault of the Matheux Mountain.

71 km. The northwestern flank of Matheux comes closer to shore, and the fault continues into the Gulf. Some elevated Pleistocene reefs can be seen along the right side of the road at Carries.

As the coastal region narrows farther north, the road runs closer to the mountain, note extensive Karst features along the slopes. Entrances to series of well known caves called "Trou Forban" can be seen toward the top of the steep mountain side. These caves were used by the Arawacks for ceremonial purposes.

73 km. Closest approach of the northwestern flank of the Matheux to shore where the fault continues northwestward into the Gulf of La Gonave. Farther northward, low hills are of Mio-Pliocene clastics which were evidently originated from the nearby paleo River of Montrouis.

More fanglomerates and elevated Pleistocene terraces appear until Mountrouis. Some well defined terraces occur in the vicinity and at the site of Hotel Xaragua (78 km).

81.2 km STOP 13: PIERRE PAYEN - Southern limit of Bois Neuf region. Yellowish-brown sandy marl. Hemipelagic facies of late Miocene age. The foraminiferal fauna is very well preserved, and very well diversified. It includes an assemblage indicative of the latest Miocene *Globorotalia margaritae* Zone.

82.1 km. Etang Bois Neuf. This small pond lies in a fault controlled depression underlain by upper Miocene to lower Pliocene sandy marl. The lake occurs about at the juncture of northwest and north-northeast trending faults (figure 3) which underwent differential displacements during the late Pleistocene. The soft marl caught in between two competent blocks buckled gently giving rise to a constriction allowing water to accumulate in the Bois Neuf area which then became permanently emergent. Morne Bois Neuf seen on the west side of the pond may have remained a separate small island off the mainland during Pleistocene high sea-stand.

88.2 km STOP 14: BOIS NEUF Outcrop of clayey sand, silstone, and intraformational mudflow (intrabasinal slump). The age is also latest Miocene *Globorotalia margaritae* Zone.

The abundance of benthonic taxa at this location indicates a depth of water shallower than the preceding station. This hemipelagic facies most likely accumulated on a deep shelf or on the slope close to the shelf edge. The depositional environment was intermittently flooded by more abundant and coarser terrigenous sediments carried by the Riviere de Saint Marc which must have existed since that time. These clastic facies are in marked contrast to the eupelagic chalk facies deposited during the early Miocene. This drastic change in the depositional regime is similar to that of the La Salle-Baoruco block (Maurrasse et al., 1982b) previously discussed. Two superimposed factors evidently contributed to the change: tectonic activities and paleoclimatic fluctuations in post early Miocene time. The dry climate which prevailed over the area during early Miocene time contributed to a dominantly pelagic regime. Contrariwise, heavy intermittent rainfalls appear to have prevailed over the area during cooler climatic conditions subsequent to early Miocene. A low sea-level would have also enhanced the flow of terrigenous supplies by allowing erosion of previously inundated shelf area. Nonetheless, areas that were either sufficiently remote from rivers, or isolated by geographic features from subaqueous flows continued to accumulate nerito-pelagic facies as seen at STOP

12. Late Miocene uplifts (Maurrasse, 1982c) further enhanced the existing climatic effects.

The composition of the clastic elements indicates a provenance compatible with the terranes of the drainage system of the present Rivière de Saint Marc.

92.0 km. Ca Perisse and Morne Rousseau on the westside of the road. Another variable clastic series crop out at the level of the road. Its age ranges from early Late Miocene to latest Miocene. The upper series going to the top of Morne Rousseau reaches the Late Pliocene *Globorotalia tosaensis* Zone. This facies also suggests near shelf break to a deep neritic environment as attest the presence of Scaphopods and other smaller Pelecypods which are characteristic of low energy muddy shelf environments. A modern analog would be the present Gulf of La Gonave at Port-au-Prince Bay.

The oldest coral reefs of this area occur as limestone cliffs capping the Pliocene marl at Morne Rousseau. Unless a paraconformity is present in between the two series, these oldest reefs may be of late Pliocene age. This is suggested by the sedimentary record which indicates that the corals developed over a gradually emerging shelf environment, much the same way the successive Pleistocene terraces developed.

96.9 km. Note elevated Pleistocene terrace at the entrance of the city of Saint Marc. The road runs on top of the second raised terrace which is covered by lateritic soil.

101 km. Northern limit of the city of Saint Marc. Steep cliff at turn consists of Miocene bioclastic and terrigenous sediments, and is part of the series to be seen farther north in the Saint Marc anticline.

102 km. Southwest limb of the northwest-southeast trending Saint Marc anticline. The calcareous sandstones, sandy foraminiferal marl beds can be seen dipping successively to the southwest.

104 km. Core region of the anticline. It comprises predominantly yellowish gray foraminiferal marl intercalated with coral rubbles in beds of variable thickness (15 centimeters average). Gypsum also occurs in cracks intersecting the whole sequence. Planktonic foraminifera are very small and include among others *Globigerina* aff. *pachyderma*, *Globigerinoides oliquus*, *Globigerinoides extremus*, *Globoquadrina venezuelana*, *Globorotalia margaritae*, and *Globorotalia pseudomiocenica*, suggesting a latest Miocene to possibly earliest Pliocene age for the oldest outcrops in the eroded core region. An exploratory well was drilled in 1947 by the Atlantic Refining Co. in an area about 500 meters from the road. The drilling results indicated the presence of lower Miocene sandy claystones and limestones comparable to lithofacies of the Thomonde Formation down

to 800 meters, terminal depth. Tests for Hydrocarbons are reported to have been negative (Rigaud and Pierre-Louis, 1982).

105 km. End of northeastern limb of the anticline. The road gradually descends the dip slope of the anticline to reach the southern rim of the Artibonite Plain. Here again you will observe a dry area which is in the rain shadow zone of the "Montagnes de Saint Marc" (figure 4).

Ahead lies the Artibonite Plain which is essentially an alluvial plain built up by sediments carried by three major rivers: 1) The Artibonite River in the central region and also the main river; 2) Rivière de l'Estère which drains the southwestern slopes of the massif of the Montagnes Noires (figure 4); 3) Rivière La Quinte, which drains the southern slopes of the Montagnes du Nord'Ouest (figure 4).

The plain is actually a fault bounded structural depression (figure 3) developed during an episode of late Paleogene distention after deactivation of the main island arc (Maurrasse, 1982c). The depression was slowly filled by the coalescing deltas as they progressed westward into the bay. Most of the plain was still under marine waters until early Pliocene, and possibly until late Pliocene as suggest marine sediments of these ages found at the easternmost end of the Mirebalais Basin, near the Central Plain (figure 12).

The northern boundary fault system or Gonaives fault zone conists of series of parallel high-angle faults which continue northwestward into the Northwestern Peninsula (figure 3). This fault zone shows evidence of some degree of left-lateral strike-slip displacement, and linear intrusions of andesitic and basaltic magmas.

134 km. Northern rim of the Artibonite Plain. Hills here consist of lithographic limestone of uncertain age, but most likely Paleogene or older. They are intruded by basaltic andesitic rocks. Butterlin (1954) and subsequent workers assigned an early Eocene age to the limestones and a Cretaceous age for the neighbouring igneous roks. In view of the fact that the latter are intruding the limestones, it is evident that the intrusions must be younger than the early Eocene age of the limestone. As we will discuss at Stop 16, the intrusions could be even younger than Middle Eocene. However, it is possible that several magmatic events took place along the major fault zone subsequent to the deactivation of the island arc (Maurrasse, 1982c, p. 163). In fact, in the Massif de Terre Neuve (figure 4), which is transected by the northwestern extension of this fault zone, Kesler (1971) reported two intrusive events. The oldest event is associated with hypabyssal basaltic plutons intruding Plaeocene and Eocene limestones. The date of the later event in the Terre Neuve area is compatible with a magmatic episode affecting medial Eocene limestones in the Gonaive area, as will also be discussed later.

125 km <u>STOP 15</u> PERISSE. Marble quarry of massive crystalline limestone varying in color from beige to gray and black, depending on the intensity of metasomatism in the rock which is intruded by hybapyssal basaltic andesite. As pointed out in the preceding paragraph, the lack of reliable fossils in these limestones make the timing of these intrusions still uncertain within post Cretaceous time.

This area is the southeastern tip of a minor horst, the Morne Grammont seen toward the north-northwest from here. This small mountain actually divides the northernmost part of the Artibonite Plain into a smaller unit called Savane Désolée, because of its sub-desertic character caused by the rain shadow effect of the adjacent Montagnes Noires.

Extensive multidirectional faults also affect the limestone whose fragments have been subsequently completely recimented in a solid competent rock, now used as rock marble.

The Morne Grammont appears to have stood as a separate island off the mainland throughout the Pleistocene. This structurally controlled mountain is a smaller analog of the Martin Garcia Mountain at the end of the Neiba Mountains (figure 2) in the Dominican Republic.

152 km. Gonaives - This city is also named after an original Arawak town which existed at this site in pre-Columbian time. It was then known as Gonaibo, and was apparently the capital city of the Caciquat of Marien which was ruled by Guacanagaric. Gonaives is also the city where Haiti was proclaimed independent in 1804.

North of Ganaives the xerophitic vegetation indicates another rain-shadow zone. From there on the outcrops along the road leading to Cap-Haitien provide excellent cross-sections of the Hispaniolan main island-arc complex.

166 km <u>STOP 16</u>. North of village of Poteaux at Morne deux Mamelles. This area is part of the northernmost extremity of the Montagnes Noires transected by major and subsidiary northwest trending faults related to the Gonaives fault zone (figure 3). Extensive metasomatism occurs in the limestone in the fault zone. The sedimentary rocks consist essentially of very light tan to white pelagic limestone, in layers 5 to 15 centimeters thick. Identifiable planktonic microfauna include <u>Globigerapsis index</u> and <u>Lamptonium fabaeforme</u>, both indicative of a middle Eocene age. Farther north there is evidence showing that a magmatic event was contemporaneous with this limestone deposit.

167 km. West of Pass Reine. These outcrops of thinnly bedded limestones formerly classified as the Ennery Formation are here equated to the Neiba formation.

174 km <u>STOP 17</u>. Limestones near Ennery. Here the eupelagic limestones similar to the one seen north of Gonaives now include intercalated beds of shallow-water biocalcirudite (figures 16,17). As pointed out in the section concerning the formations, the biocalcirudite beds are allochtonous materials brought into the deeper water environments by intermittent basin-edge turbidites. Here also spatial distribution of coeval facies indicates the presence of shallow banks adjacent to deep waters at the time of deposition of these rocks. The modern analog of such environment can be found in the present day lesser Antilles island arc, where there are fault-controlled intervening deep basins between inactive volcanic banks and the active volcanic islands. Note conspicuous groove casts and load casts at the bottom of the thickest (about 150 centimeters thick) bioclastic turbidite layer. Chert stringers can also be observed interspersed in the layer. The cherts are post depositional to the turbidite event, and developed by pervasive diagenetic silicification in scattered spots of the deposit. Thinner bioclastic turbidite layers may exhibit more extensive silicification, as can be seen in such a layer (15 centimeters thick) which occurs about 250 centimeters below the thickest turbidite. As previously mentioned, the limestone fragments found in the turbidites are identical to the shallow-water facies of the Plaisance limestone proper, which we will see near the Puiboreau pass at STOP 19.

More outcrops of the limestone facies seen at STOP 17 can be observed at 176 km and 180 km road posts, respectively.

181 km. At 1 kilometer west of junction road leading to Ennery, and less than 100 meters or so west of bridge crossing "Rivière d'Ennery". Here the thinnly bedded limestone of the Neiba type of facies is mixed with a basaltic agglomerate layer 5 to 6 meters thick. This volcanic event is apparently corelative with the magmatic event which caused metasomatic alteration in the limestone sequence seen at STOP 16. The planktonic microfauna found associated with this pyroclastic layer also yielded a Middle Eocene age, consistent with the age assignment given by previous authors (Woodring et al. 1924; Butterlin, 1954). More spectacular agglomerates, (fig. 28B) and also pillow-lavas will be observed along the road cuts of the southern flank of Morne Puilboreau, which is the mountain range immediately north of here.

182 km. Junction new section of road "Nationale 1" and the old section leading to Ennery.

183.2 km <u>STOP 18</u>. Lower foothills of Morne Puilboreau. Yellowish brown foraminiferal marl intermixed with subaqueous igneous flows. These middle Eocene eruptive events were apparently not associated with distinct volcanic structures, which suggests that they may have taken place along major fault zones during the Upper Paleogene dislocation of the original main island arc (Maurrasse, 1982c). Similar fissure eruptions were reported by Burbank (in Woodring et al., 1924) in the Montagnes de Terre Neuve northwest of here. The petrology of these rocks, also studied by Burbank, indicates that they are analcite andesites and analcite-olivine andesites, or transistional between the essexite and other types of basalts found farther north. Microscopically the plagioclase is strongly zonal and ranges in composition from labradorite to sodic oligoclase albite. Because of the irregular borders of sodic plagioclase the interlacing prisms are never strictly euhedral. In some cases, small amounts of soda orthoclase is found in between the plagioclases. Plagioclases generally amounts to 40 or 50 percent of the rock. Purple pleochroic augite occurs in subordinate amount, forming 20 to 30 percent of the rock. Olivine was apparently a primary constituent in some of the rocks but is altered to iddengsite. Analcite and/or natrolite may also fill spaces between the plagioclase and replace the feldspars to a variable extent (Burbank, in Woodring et al., 1924). The marl contains abundant planktonic foraminifera of a mixed assemblage including older taxa from the upper Paleocene Globorotalia pseudomenardii zone, and younger taxa of the upper Middle Eocene Orbulinoides beckmanni zone.

I should point out that the "Crête Sale" Formation of Butterlin (1957) described from similar sequences found southeast of Ennery is here considered to be a lateral facies, or a member of the series found in this area. The sequences described by Bulterlin may have been closer to the eruptive center, as they include a relatively greater porportion of pyroclastics than those cropping out here. As I noted earlier, these volcanic eruptions may have been related to distention in first and second order shear zones which developed in the left-lateral wrench fault tectonic system of the northern boundary of the Caribbean plate (Maurrasse, 1982c; Maurrasse et al., 1982b). Their modern analog can be examplified by the pesent situation in the lesser Antilles where alkaline volcanic series and olivine rich sub-alkaline basalts occur in relation to NE- SW and SE-NW trending faults crossing the archipelago and dislocating the Caribbean crust into large blocks (Westercamp, 1980). In the lesser Antilles arc tholeiitic series characterize the first stage of activity, while the actual stage of maturity is characterized by primary calc- alkaline suites (Westercamp, 1980).

183.9 km. Agglomerates intercalated with pelagic chalk. The chalk here is remarkably rich in Chilogumbelinids. The presence of Globigerinatheka barri indicates a late Middle to earliest Late Eocene age for the sequence.

It is worth noting that a lithofacies similar to this outcrops occurs farther west in the valley of the "Trois Rivières" about 1.8 kilometer north of "Rivière Gros Morne". However, in the latter area the foraminiferal fauna includes Globorotalia Kugleri, indicative of an earliest Miocene age for that sequence. It is thus evident that during Middle Cenozoic the northern part of Hispaniola went through several episodes of fissures eruptions in the areas of major dislocation. Eruptive centers are known indeed to have become active in these faulted areas until the Pleistocene (Woodring et al., 1924; Butterlin, 1954). The youngest eruptive centers with defined volcanic structures are known in Haiti, near Thomazeau and Saut d' Eau, and in the western Dominican Republic, near San Juan de la Maguana and Rio Yaque del Sur in the Sierra de Neiba, Sierra de Ocoa. Pleistocene eruptive centers are also known in the Cordillera Central, south-southeast of Peak Duarte (figure 2). Their absolute age has been determined to be less than one million years (Vespucci, 1980).

187.5 km. Andesitic agglomerates in chalk of late Middle Eocene age. Sedimentary structures indicates a subaqueous flow within close proximity of a volcanic center.

188.5 km. STOP 19. Chalk facies of the Jérémie Formation. Here the rock series is of late Middle Eocene age, and possibly early Late Eocene. Like its younger analog at Stop 11, it is also characterized by the dominance of Chilogumbelinids in the foraminiferal assemblage. This same facies occurs farther west in the Massif du Nord'Ouest (figure 4) where the outcrops range in age from the latest Early Eocene, *Globorotalia aragonensis* zone, to the early Middle Eocene *Hantkenina aragonensis* zone. I should also point out that despite the absence of distinct layers of intrabasinal bioclastic turbidites in these series, the older levels in the Massif du Nord'Ouest also include reworked middle Paleocene foraminiferal fauna.

190.4 km. Recurrence of andesitic agglomerates in chalk.

191.4 km. Thickly bedded biocalcirudite and biocalcarenite of the Plaisance limestone lithofacies proper, as originally designated by Vaughan (1921, in Vaughan et al., 1921).

192 km. STOP 20. PUILBOREAU COL. Altitude 950 meters. Here you can see the typical Plaisance limestones which form a prominent northwest-southeast trending divide between the limestone terranes to the south-southwest and the igneous terranes to the north-northeast. The transition between this shallow water facies and the coeval deep-water chalk is quite abrupt in this area. In fact, thrust contact is suggested, as can be seen in an outcrop about 500 meters south of the pass.

The Plaisance limestone facies developed over fault-controlled banks bordered by deep water basins to the south and both active and extinct volcanoes to the north. Clear waters apparently prevailed over the banks which sustained prodigious productivity of benthic foraminifera. The most characteristic species of these limestones are *Dictyoconus puilboreauensis* and *Dictyoconus codon*. The abundance of calcareous green algae further indicates that the depth of the bank stayed within the euphotic zone, and probably within the reach of wave base. Intermittent turbidites containing elements from the bank as observed at Stop 17 may have been triggered by heavy storms which disloged abundant materials from the bank surface.

As we proceed down on the steep winding road along the northeastern slope of Morne Puilboreau observe further outcrops of the limestone which is also extensively fractured throughout.

198 km. Contact between the sedimentary rocks and the igneous complex (here dacite and andesite) which constitutes the hearthland of the northern part of Hispaniola. From here on we will be crossing the volcanic island arc of early Hispaniola.

199.5 km. Outcrop of lithofacies of the "Trois Rivière" Formation south of the bridge crossing the Trois Rivières immediately south of the town of Plaisance. Note tightly folded and sheared inter-bedded series of dark brown fine-grained sandstone, sandy-shale and argillite.

205 km. Plaisance.

207.2 km. Contact between pure argillite and thinnly bedded limestone with chert of Trois Rivieres Formation, and partially weathered andesite of the old island arc complex. The limestone includes ghost of Radiolaria which are indicative of an open marine environment. Here the intercalation of argillite and volcanogenic turbidite with the pelagic limestone suggests proximity to the volcanic center. Rocks of this formation are time correlative with those of the Macaya Formation (figure 11), which also represent hemipelagic facies generated in similar geologic environment at the distal portion of the Nicaragua Rise-Jamaica island-arc system (Maurrasse, 1982c). Unlike these island-arc deposits, the Dumisseau Formation seen along the transect of the Southern Peninsula is the result of basaltic eruptions related to back-arc spreading.

206.2 km. Andesitic agglomerate.

208.1 km. Gray hornblende andesite.

208.2 km. Pyroxene andesite, gray to greenish in color. It also shows minor shearing structures.

208.3 km. Basaltic andesite, very dark gray to greenish gray, with birdseye tuff indicative of explosive volcanic activity. The abundance of pyroxene in the pyroclastic may also indicate closeness to the volcanic vent.

209.2 km. "Col du Bedeuret". 500 meters altitude. Mountain pass controlled by fault systems transecting the igneous complex.

212.7 km. North flank of Morne Bedeuret with outcrops of andesite, dacite and metadiabase.

216 km. Foothill of the Morne Bedeuret with outcrop of quartz diorite.

233 km. Plaine du Nord. This area of the northern Plain is alluvial and became emergent at the end of the Pleistocene. The city of Cap-Haitien is at the northerwestern outskirt of the Plain where an outlier of Cretaceous sedimentary rocks forms a smaller mountain chain called "Morne du Haut du Cap" which formed a separate island offshore prior to the Holocene emergence of the region.

263 km. Gateway at the south side of the city of Cap Haitien (ex Cap Francais) often called the Paris of the Antilles (West Indies) during the colonial time. Observe fault contact between hemipelagic cherty sequence and porphyritic igneous rock. Shortly after independence from France, Haiti became divided and Cap Haitien became the capital of the Northern Kingdom led by Henri Christophe the builder of the Citadelle. The city was then called Cap Henri. Its present name became in use after the death of Henri Christophe in 1820.

Most of the city lies on alluvium accumulated along northeast-trending fault systems transecting the Morne Calvaire/Morne du Cap outlier. Contacts between the island-arc igneous suite and Cretaceous rocks attributable to the Trois Rivières formation are also fault controlled in the area. As pointed out by Woodring et al (1924) a typical sequence of the latter formation occurs along the shore near Carénage, the most northerly section of the city. It consists of interbedded brown to yellow silstone, claystone, fine sandstone marl, dense black and blue chert stringers. Maximum thickness of beds is about 25 centimeters, but there are levels where closely spaced chert beds may reach thicknesses of several meters. Like similar chert beds found in the Dumisseau Formation (Maurrasse et al., 1979a) in the Southern Peninsula, the thick chert beds are apparently of volcanogenic origin. Nonetheless, while the series observed at Cap Haitien can be attributed to a hemipelagic sequence deposited in the fore-arc basin of an island-arc system, those observed in the Southern Peninsula are pelagic and thought to have been deposited in the back-arc area (Maurrasse, 1982c).

SUMMARY AND CONCLUSIONS

The geologic transects of Haiti discussed in this field guide provide the basic information necessary to understand the fundamental differences between the northern and southern portions of Hispaniola separated by the prominent Cul-de-sac/Enriquillo depression (figure 3). The transects also allow for further paleogeographic interpretation of the western area of Hispaniola with extrapolation on the eastern area of the island as a whole

The geologic data at hand clearly show that during late Mesozoic time an active island-arc system(s) existed in the northern portion of Hispaniola north of the present Cul-de-Sac/Enriquillo depression. It was characterized by extensive alkaline and calcalkaline eruptive activities. On the other hand the geologic record of that time in the Southern portion of the island exhibits tholeiitic basalts suggestive of an origin from a possible back-arc environment for their petrogenesis (Maurrasse, 1982c; Maurrassee et al.,

PALEOGEOGRAPHY OF HISPANIOLA

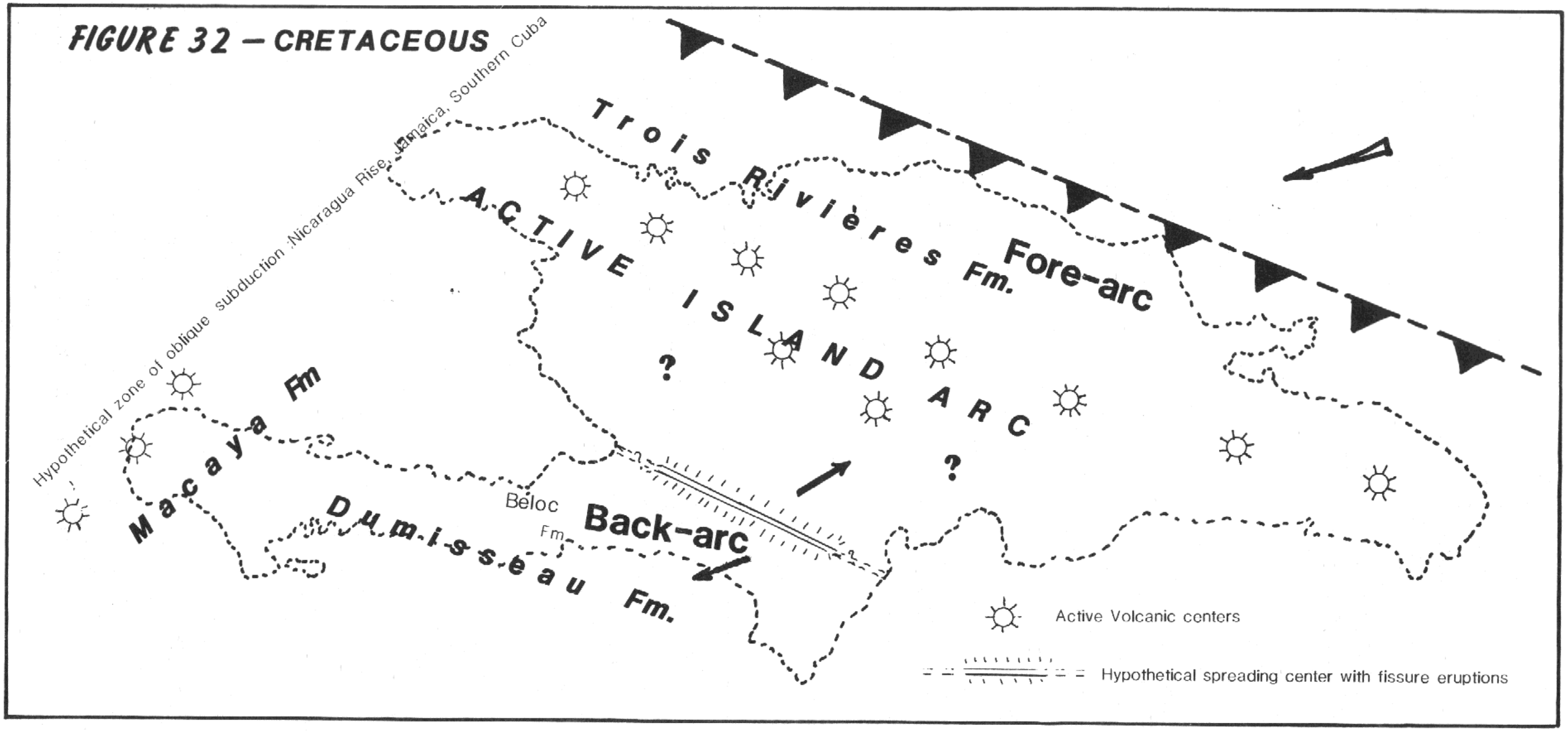


FIGURE 32 — CRETACEOUS

1979a). Although subaerial volcanoes may have developed in the island arc during Early to Middle Cretaceous times, most of the areas which constitute present Hispaniola were under deep water. Terrigenous sediments accumulated in the fore-arc and intravolcanic basins of the arc system. Such sediments are typified by the series of the Trois Rivieres Formation in Haiti and the Los Ranchos Formation in the Dominican Republic. The first clear evidence of lands in the island-arc system is given by the presence of plant fossils in a lens of black limestone in the Platanal Member of the Los Ranchos Formation (cf. page 11) of Early Cretaceous age. In addition to sub-aerial built-up of volcanoes, the islands may have also been the results of pre-Albian tectonic disturbances as discussed in page 11.

The presumed south-dipping descending lithoshere along the island arc is inferred to have created a downward body force on the underthrusted proto-Caribbean plate which was then pulled toward the trench. This phenomenon of trench suction evidently created intraplate extension normal to the island-arc. Necking led to pressure release at the base of the proto-Caribbean lithospheric plate. Further strains caused rupture and abundant fissure eruptions associated with back-arc spreading induced by magnatic decompression in areas of maximum tensile stresses. The Dumisseau Formation (p. 13) provide the record of such activities, the Macaya Formation (p. 12) accumulated farther west in the fore-arc basin of another subduction zone including the Nicaragua Rise and Jamaica. There is no evidence of land masses in the southern areas of Hispaniola at that time (Figure 32).

This early setting was apparently severely modified by Santonian-Campanian time when back-arc and island arc activities gradually ceased in the region. Major dislocations occurred at that time giving rise to individualized blocks, some of which became temporarily shallow-banks in the Southern portion of present Hispaniola, but there were still no emerged lands in this area. Pelagic conditions of sedimentation remained over most of the Southern Peninsula from the Maastrichtian (Stops 6,7,8) through the Paleocene/Eocene when differential uplift may have given rise to the first scattered islands in that area (Figure 33).

From the Paleocene on, time of elevation of the different areas which will eventually lead to present day Hispaniola will differ. The predominant paleogeographic characteristics of the Early Tertiary was that of structurally controlled banks and islands separated by deep-water basins (figures 33,34). Such situation is comparable but not quite analogous, to the present-day Bahamas archipelago, which does not comprise volcanic islands. Pelagic chalk accumulated in the deep areas away from the terrigenous materials coming from eroding islands and banks which collected in the adjacent intervening troughs or deep basins. The Abuillot and Marigot Formations are examples of the terrigenous deposits, whereas the Jérémie and Neiba Formations (Stops 4,6,7,8, 19 and figures 15,17) examplify the pelagic series of that time. Shallow-water limestones deposited over the banks are represented by the Plaisance Formation (Stop 20) in Haiti and the Hidalgos Formation in the Dominican Republic. Paleo-oceanographic condition over these carbonate banks prevented the development of bioherms, a situation which persisted indeed in the area until the latest Piiocene. A modern analog of such a situation is perhaps best illustrated by Cay Sal bank off the coast of Cuba in the Straits of

PALEOGEOGRAPHY OF HISPANIOLA

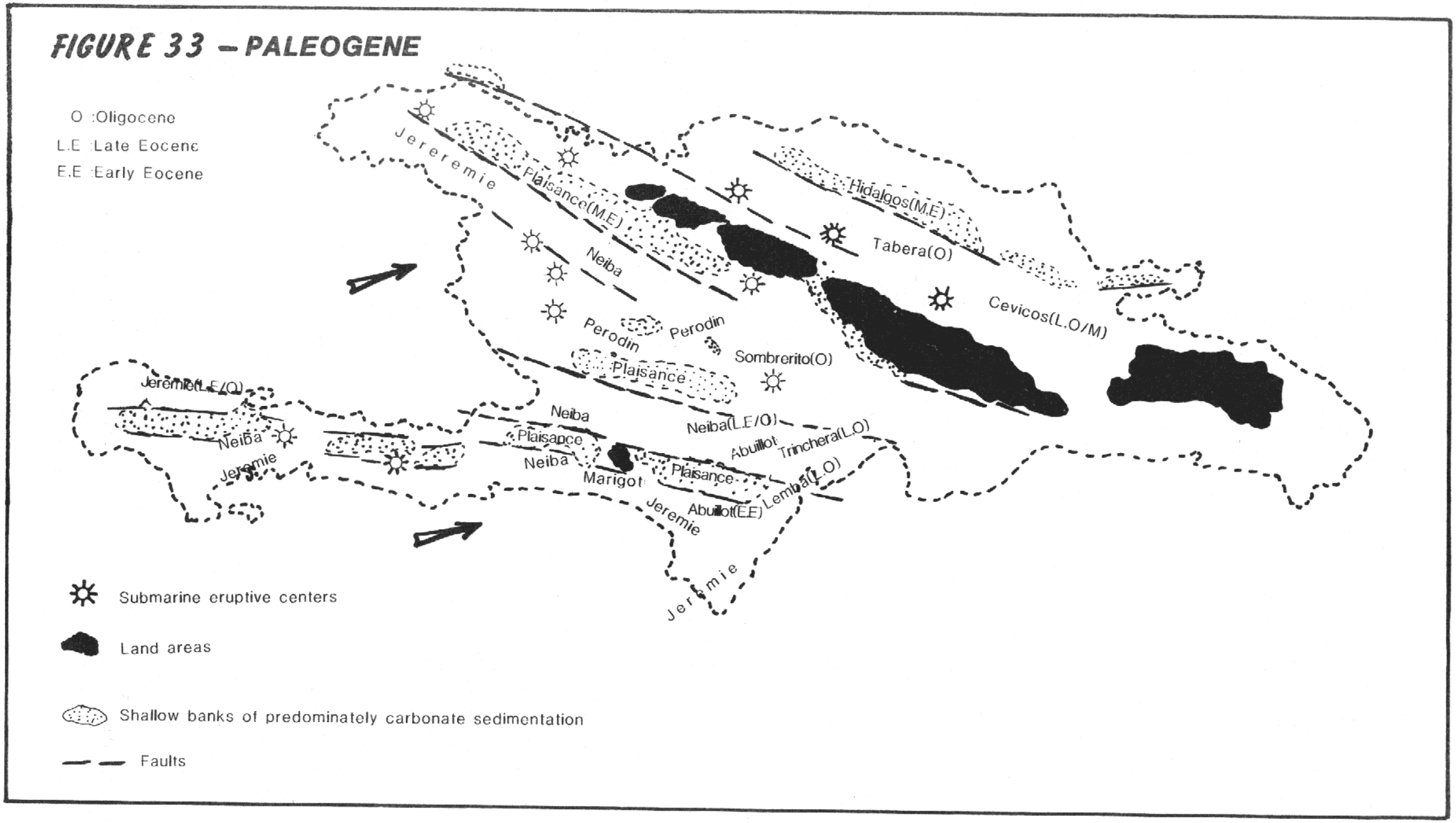


FIGURE 33 – PALEOGENE

Florida. Biogenic turbidites coming from the banks could occasionally reached the eupelagic environments as are illustrated in outcrops at Stops 11 and 17 (figures 16,17). There is also evidence of extensive volcanic activities during the Paleogene as attest magmatic metasomatism observed at Stop 17, the eruptive events of Stop 18, and agglomerates seen therafter (see also the Perodin Formation). The absence of well defined eruptive centers at the time indicates that fissure eruptions were evidently associated with further dislocations of the upper Mesozic island arc system. Tectonic deactivation of the initial island-arc, and differential isostatic uplift of individualized blocks were apparently related to compression and distention caused by left-lateral motion along the northern boundary of the Caribbean plate (Maurrasse, 1982c). Distention with strike-slip displacement along the northern Caribbean plate megashear also caused pull-apart zones to occur within the dislocated former island arc and the adjacent Caribbean basin. Thus, Hispaniola at that time became characterized by fault-bounded alternating subsiding linear basins separated by rising land masses. The independent and progressive rise of these structural blocks are recorded by the diachrony of facies observed in the different blocks covered by the transects.

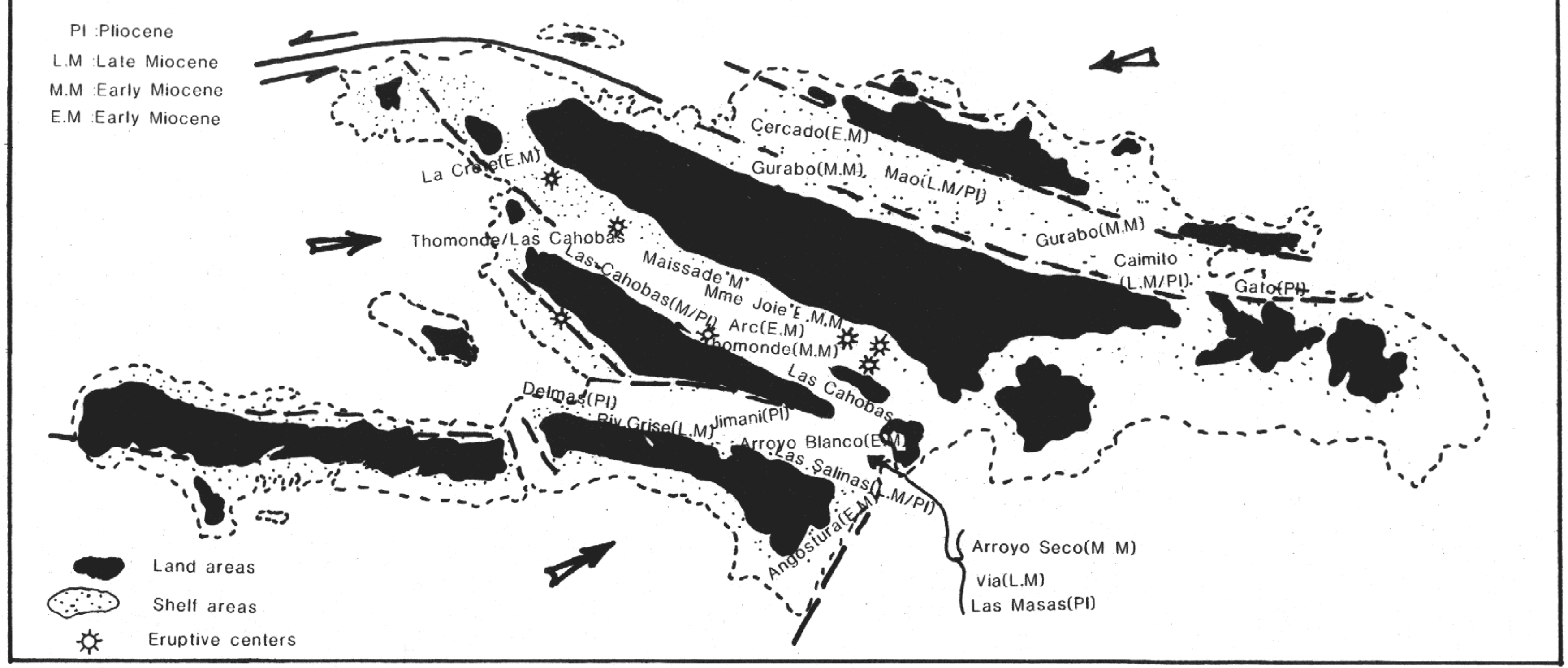
The sedimentary regimes of Hispaniola from Middle Paleogene onward were essentially influenced by the structurally controlled physiography. Thick clastic sediments started to accumulate in the basins as evidenced by widespread terrigenous series at that time, such as the Sombrerito, Trinchera, Villa Trina, Lemba and Florentino Formations in the eastern areas of the island (Figure 33).

At the onset of the Miocene the tectonic setting and the sedimentary regimes over Hispaniola were continuation of those which prevailed in Late Paleogene time. However, the sedimentary record of the basins adjacent to the existing land masses (figure 34) indicates that the lower Miocene series accumulated rather in neritopelagic environments, a trend which continued diachronously through the final emergence of all the initial islands into a single land mass by the close of the Pliocene through middle Pleistocene (Figures 19,20). The depositional regime in the subsiding deep-basin also show substantial shallowing in the Late Pliocene as attest most of the series of that time throughout Hispaniola. In addition to tectonic disturbances, the climatic fluctuations of the Neogene also appear to have played a major role in clastic sedimentation of that time. As illustrated by the sequences observed at Stops 2 and 14, periods of neritopelagic to moderately terrigenous hemipelagic sedimentation were periodically interrupted by massive influx of coarse terrigenous detritus which were apparently carried by flood stages of the existing drainage systems (Maurrasse et al. 1982b).

Thus, clastic sedimentation during the Neogene increased not only because of increasingly more emerging areas exposed to erosion, but also because of pronounced climatic fluctuations at that time. Thick clastic sediments, often in excess of 3,000 meters accumulated in the subsiding marine depressions between the rising land masses (figures 34). Large deltas and submarine fans also developed along the steep, fault-bounded margins of the emerging Hispaniolan archipelago. It was apparently also the time when proper geographic and climatic conditions became established to favor bauxitization and subsequent preservation of the soils in developing Karst terranes. Like

PALEOGEOGRAPHY OF HISPANIOLA

FIGURE 34 NEOGENE



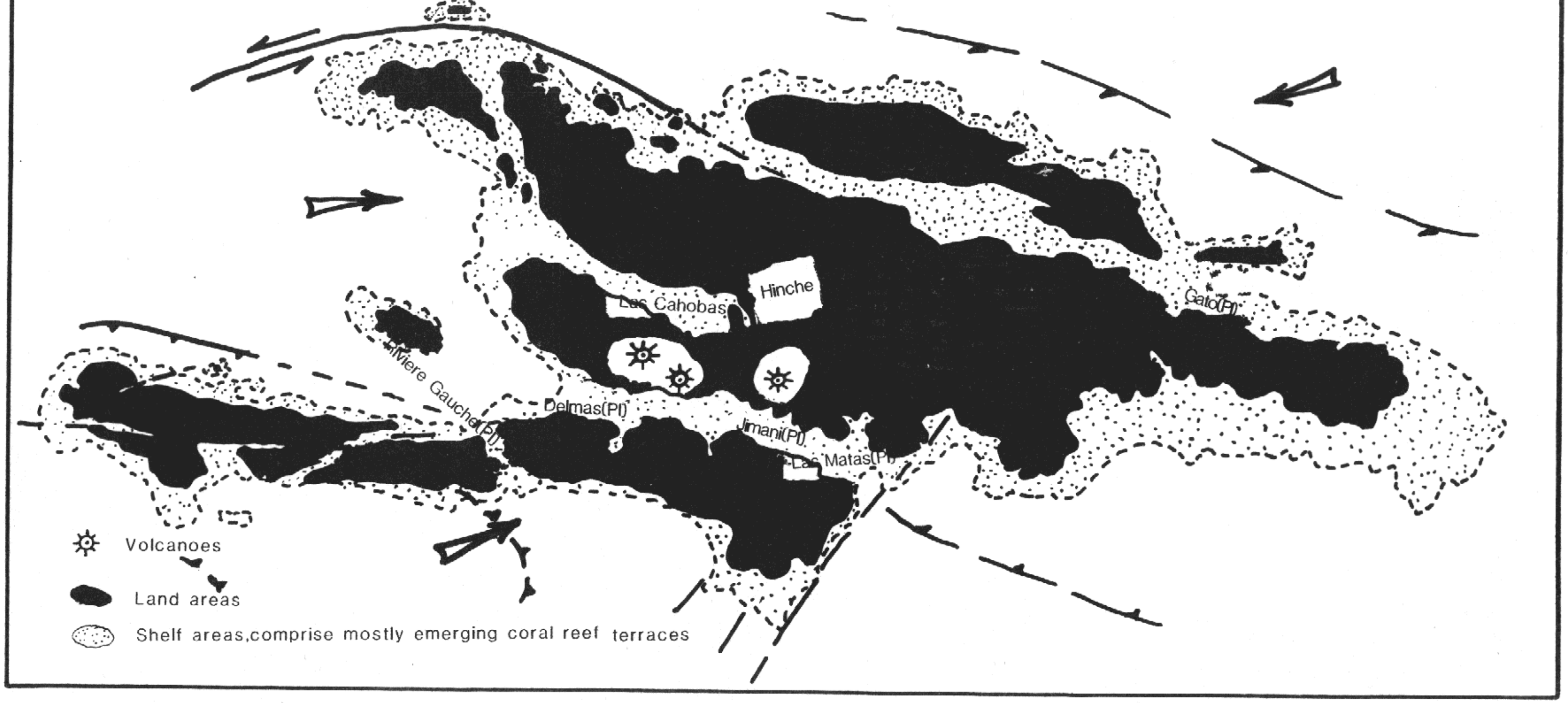
in the Paleogene, renewed volcanic activities through the Neogene were apparently related to major restructuration along the main fault systems. Much of the volcanic products of subaerial eruptions in the northern regions may have been carried south, south-westward by the Trade winds and accumulated over existing reliefs. The ashes greatly contributed to the initial lateritic soils at the origin of the bauxites, as observed on the Plateau de Rochelois near Paillant (Figures 18,31).

By Late Pliocene time the general configuration of the island of Hispaniola began to approach closely that of the present. Nonetheless, relicts of subsiding basins collecting terrigenous detritus from the adjacent emerging islands still persisted in certain areas (Figure 35). The Cul-de-Sac/Enriquillo depression, for instance, became totally closed only during the Pleistocene. Plio-Pleistocene uplift coupled with concomitant glacio-eustatic sea-level fluctuations led to the raised reef terraces (Figure 5) so characteristic of the western and southern areas of present Hispaniola. Like in the early period, uplift rate during the Pliocene and Pleistocene varied in the different areas of Hispaniola. On the whole the northern areas uplifted at a much faster rate than the southern areas (Dodge et al 1983). The discrepancy is believed to be related to crustal tilting of the northern Caribbean plate boundary in the regions adjacent to the Cayman trench (Horsfield, 1977). The Pleistocene represents the crucial stage in the development of Hispaniola because then the various islands of the archipelago became consolidated by further constriction of the intervening basins. Compressional forces also caused additional reverse faulting thrusting and tilting of pre-existing structures. Folding of the thick clastic wedges of the basins or through-shaped depression also occurred at that time. Reactivation of some of the fault-systems may have been accompanied by distention, further mantle decompression and volcanism, as attest the eruptive centers north of the Cul-de-Sac/Enriquillo depression. The newly raised areas and those already emergent prior to the Pleistocene yielded sediments to the neighboring basins which finally developed alluvial plains by progradation of the delta systems, a process still active along the margins of Hispaniola. Delta progradation has been accelerated in recent times by deforestration of the upland areas as can be examplified in the bay of Port-au-Prince. Hispaniola is still tectonically active as is indicated by a history of destructive earthquates which occurred in the past hundred years along the Trans-Xaragua fault system, and most of the fault systems in the northern portion of the island and their seaward extension into the canal de la Tortue (Figure 3).

As a brief recapitualation it can be said that the portion of Hispaniola north of the Cul-de-Sac/Enriquillo depression has been formed by a multistage process of accretion which started with an early primitive island arc system beginning about Late Jurassic or Early Cretaceous. Trench suction and associated necking of the back-arc area apparently led to back-arc spreading in the region now comprising the Southern Peninsula of Haiti and its eastern extension in the Baoruco mountains of the Dominican Republic. Late Santonian to Campanian restructuration of the incipient Caribbean plate resulted in dislocation of the preexisting tectonic setting and the development of volcanic islands and banks in the northern region forming the initial archipelago which evolved into the northern portion of Hispaniola. Similar

PALEOGEOGRAPHY OF HISPANIOLA

FIGURE 35 - LATE PLIOCENE to LATE PLEISTOCENE



dislocation in the back-arc area also led to the development of banks probably by Late Cretaceous and certainly as early as the Paleocene. Raised volcanic islands and banks yielded clastic sediments to adjoining subsiding structural depressions. Late calcalkaline magmatism also occurred in relation to various tectonic episodes throughout the Tertiary. The rifted depressions finally became consolidated with the preexisting islands and emerging banks of the archipelago during the Pleistocene.

BIBLIOGRAPHY

Alvarez, W., F. Asaro, L.W. Alvarez, H.V. Michael, M. Arthur, W. Dean, D. Johnson, M. Kastner, F. Maurrasse, R. R. Revelle and D. A. Russell, 1982, New data on the Cretaceous Tertiary extinction: Abs. AAAS Annual Meeting, Washington, D.C.

Anonymous, 1980, Field Trip B, Gold deposits Pueblo Viejo, Rosario Dominicana: Road log. 9th Carib. Geol. Conf. Field Guide, p. 51-60.

Ayala-Castanares, A. 1959, Estudio de algunos microfosiles planctonicos de la calizas del Cretacico Superior de la Republica de Haiti Plaeont. Mexicana 4:41 pp.

Bermudez, Pedro Joaquim 1949, Tertiary Smaller Foraminifera of the Dominican Republic: Cushman Laboratory for Foraminiferal Research, Special Publication No. 25, Sharon, Massachussets, U.S.A. (December 21, 1949); 322 p., 26 plates.

Biju-Duval, A., Mascle, L. Montadert and J. Wanneson, 1978, Seismic investigations in the Colombia, Venezuela and Grenada Basins and on the Barbados Ridge for future IPOD drilling in H.J. MacGillavry and D.J. Beets editors: the 8th Carib. Geol. Conf. (Willemstad 1979), Geol. Minjbouw, v. 57, p. 105-116.

Bowin, C, 1966, Geology of Central Dominican Republic: A case History of part of an island arc: The Geological Society of America, Memoir 98, p. 11-84 + 5 Plates.

Bowin, C, 1968, Geophysical study of the Cayman Trough: Jour. Geophys. Res., v. 73, p. 11-84.

Bowin, C, 1975, The Geology of Hispaniola: in A.E.M. Nairn and F.G. Stehli, editors, The Ocean basins and margins, vol. 3, p. 501-552.

Boyce, R.E., 1973, Physical properties summary, in N.T. Edgar et al., 1973, Initial Reports of the Deep Sea Drilling Project, v. 15, Washington (U.S. Government Printing Office) p. 1067-1068.

Bracey, D.R. and P.R. Vogt, 1970, Plate tectonics in the Hispaniola area: Geol. Soc. America Bull., v. 81, p. 2855-2860.

Burbank, S.W., 1924, Igneous rocks, in W.P. Woodring et al., Geology of the Republic of Haiti: Department Travaux Publics, Haiti, p. 260-330.

Burke, Kevin, P.S. Fox & A.E.C. Sengor, 1978, Buoyant ocean floor and the evolution of the Caribbean: Jour. Geophys. Res., v. 83, No. 138, Aug. 10, 1978, p. 3949-3954.

Butterlin, Jacques, 1950, Contribution à l'Etude de la géologie de la Bordure Sud du Cul-de-Sac (Haïti, Grandes Antilles): Société Haitienne d'Histoire, de Géographie et de Géologie, rev. No. 76, vol. 21, p. 1-79.

Butterlin, J. 1954, La Géologie de la République d'Haïti et ses rapports avec celle des régions voisines: publ. comm. 150e. anniversaire de l'Indépendance d'Haïti, secret. presid. (Port-au-Prince): 446 pp.

Butterlin, Jacques, 1957, Les Formations écocenes sédimentaires et ignées des Montagnes Noires (République d'Haïti) et leur importance pour l'histoire géologique des Antilles: Soc. Geol., France, Bull. 6e sér., vol. 7, p. 505-517, 1 fig.

Butterlin, Jacques, 1960, Géologie Générale et Régionale de la République d'Haïti: Mém. Inst. des Hautes Etudes de l'Amérique Latine, VI, Paris, 194 p. 18 pls.

Case, J.E., 1974, Major basins along the continental margin of Northern South America, in C.A. Burk and C.L. Drake, editors, The Geology of Continental Margins, Springer Verlag, p. 733-741.
Case, J.E., 1975, Geophysical Studies in the Caribbean Sea: in A.E. M. Nairn & F.G. Stehli (eds), The ocean basins and margins, v. 3, p. 107-180.
Case, J.E. and T.L. Holcombe, 1980, Geologic-tectonic map of the Caribbean region: U.S. Geological Survey Miscellaneous Investigations Map I-1100, scale 1: 2,500,000.
Cheilletz, A., 1976, Etude géologique et métallogénique des indices àcuivre et molybdène de type porphyre cuprifère de la zone de Vert de Gris, Jean-Rabel, Presqu'ile du Nord-Quest, Haïti: Thèse de 3e cycle, Univ. Nancy, France, 182 p. + figs.
Christofferson, E., 1973, Linear magnetic anomalies in the Colombia Basin, Central Caribbean Sea: Geol. Soc. Amer. Bull. v. 84, p. 3217-3230.
Christofferson, E. 1976, Colombia Basin magnetism and Caribbean plate tectonics: Geol. Soc. Amer. Bull. v. 87: p. 1255-1258.
Coleman, R.G. 1977, Ophiolites, ancient oceanic lithosphere?: Springer-Verlag Min. Rocks Series 12: 229 pp.
Cooke, C.W., 1920, The Stratigraphic significance of Orthaulax: Geol. Soc. America Bull., v. 31, p. 206.
Crews, P., 1978, Petrology and stratigraphic relations of a mafic volcanic complex and associated sediments of an ophiolite in Southern Haiti: Masters Thesis, University of Florida, Gainesville. 82 p.
Del Busto Alvarez, R., 1975, Las Terrazas marinas de Maisi: Ciencias, Serie 7, Geografia, No. 10, (Centro de Informacion Cientifica y Tecnica Universidad de la Habana, Cuba), p. 1-12. plus figures.
Dengo Gabriel, 1973, Estructura Geologica, Historia Tectonica y morfologia de America Central: Instituto Centre-Americano. de Investigación y Tecnologia Industrial (ICAITI), Guatemala (Segunda edicion revisada) 1973, 52p.
Diebold, J.B., P.L. Stoffa, P. Buhl, an M. Truchan, 1981, Venezuela Basin crustal structure: Jour. Geophys. Res. v. 86, No. 39, p. 7901-7923.
Dodge, R.E., R.G. Fairbanks, L.K. Benninger and F. Maurrasse, 1981, Elevated Pleistocene coral reefs of Haïti: Uranium series dating: Geol. Soc. America, Ann. Meeting. Abs. v. 13, No. 7, p. 440.
Dodge, R.E., R.G. Fairbanks, L.K. Benninger and F. Maurrasse, 1983, Pleistococene sea levels from raised coral reefs of Haïti: Science, v. 219, p. 1423-1425.
Donnelly, Th. W. & J.J.W. Rogers, 1978, the distribution of igneous rock suites through the Caribbean, in H.J. Mac Gillavry & D.J. Beets (eds): The 8th Caribbean Geological Conference (Willemstad, 1977), Geol. Mijnbouw, v. 57: p. 151-162.
Draper, G., and J.F. Lewis, 1980, structure, petrology and tectonics of the Amina schists, north-central Dominican Republic: 9th Carib. Geol. Conf. Santo Domingo, Dominican Republic, Abs. p. 18-19.
Edgar, N.T., J.I. Ewing & J. Hennion, 1974, Seismic refraction and reflection in Caribbean Sea: Amer. Assoc, Petrol. Geol. Bull. v. 55: p. 833-870.
Edgar, N.T., J. B. Saunders, H.M. Bolli, R.E. Boyce, W.S. Broecker, T.W. Donnely, J.M. Gieskes, W.W. Hay, R.M. Horowitz, F. Maurrasse, H. Perez Nieto, W. Prell, I. Premoli-Silva, W. Riedel, N. Schneidermann, L.S. Waterman, 1973, Initial Reports of the Deep Sea Drilling Project, V. 15, Washington (U.S. Government Printing Office) 1137 p.

Ewing, J., J. Antoine and M. Ewing, 1960, Geophysical measurements in the western Caribbean Sea and in the Gulf of Mexico: Jour of Geophys. Res., v. 65, p. 4087-4126.

Ewing, J., M. Talwani & M. Ewing, 1965, Sediment distribution in the Caribbean Sea: Proc. 4th Caribbean Geol. Conf. p. 317-323.

Ewing, J., M. Talwani, M. Ewing & N.T. Edgar, 1967, Sediments of the Caribbean: in Study in tropical oceanography, Univ. Miami 5, p. 88-102.

Foreman, H., 1973, Radiolaria of leg 10 with systematics and ranges for the families Amphipyndacidae, Artostrobiidae, and Theoperidae; in J.L. Worzel et al., 1973, Initial Reports of the Deep Sea Drilling Project, v. 10, Washington (U.S. Government Printing Office), p. 407-474.

Frankel, A., 1982, A composite focal mechanism for microearthquakes along the northeastern border of the Caribbean plates: Geophys. Res. Letters, v. 9, No. 5, p. 511-514.

Frost, S., 1972, Evolution of Cenozoic Caribbean coral faunas: in Transactions 6th Caribbean Geol. Conf., Margarita. Venezuela, p. 461-464.

Hafner, W., 1951, Stress distributions and faulting: Geol. Soc. America, Bull, v. 62, p. 373-398, 1 pl.

Hopkins, H.R., 1973, Geology of the Aruba Gap Abyssal Plain near DSDP Site 153; in N.T. Edgar et al.: Initial Reports of the Deep Sea Drilling Project 15: 1039-1050.

Houtz, R. & J. Ewing, 1976, Upper crustal structures as a function of plate age: Jour Geophys. Res. v. 81, p. 2490-2499.

Hunerman, A.E., 1972, Mid Tertiary biostratigraphy of the Central Plateau of Haiti: M.S. Thesis, Louisiana State University, U.S.A., 107 p.

Jones, R.G., 1918, A geological reconnaissance in Haiti, a contribution to antillean geology: J. Geol. v. 26, p.728-752.

Kent, D.V., 1977, An estimate of the duration of the faunal change at the Cretaceous-Tertiary boundary: Geology, V. 5, p. 769-771.

Kent, D.V., and F. Maurrasse, 1982, Paleomagnetic results from the Cretaceous Dumisseau Formation of Haiti: in F. J-M.R., Maurrasse, editor, Transactions 1er Colloque sur la Geologie d'Haïti, Port-au-Prince, 27-29 Mars 1980, p. 236-244.

Kesler, Stephen E. 1971, Petrology of the Terre-Neuve Igneous Province, Northern Haiti: in Donnelly, Thomas W., editor, Caribbean Geophysical, Tectonic and Petrologic studies: Geological Society of America Memoir, 130 p. 119-137.

Kesler, S.E., J.F. Sutter, L.M. Jones and R. L. Walker, 1977, Early Cretaceous basement rocks in Hispaniola: Geology, v. 5, p. 245-247.

Kesler S.E. and J.F. Sutter 1979, Compositional evolution of intrusive rocks in the eastern Greater Antilles Island arc: Geology v. 7 no. 4, p. 197-200.

Krushensky, R.D., 1978, Unconformity between Cretaceous and Ecocene rocks in central Puerto Rico: a concept rejected, in Mac Gillavry, H.J., and Beets, D.J., editors: The 8th Caribbean Geol. Conference (Wilhemstad, 1977), Geol. Mijnbouw, v. 57, No. 2, p. 227-232.

Ladd, J.W. 1976, Relative motion of South America with respect to North America and Caribbean tectonics: Geol. Soc. Amer. Bull. v. 87, p. 969-976.

Ladd, J.W. & J.S. Watkins, 1977, Compressional features of the northern and southern margins of the Venezuela Basin and layering within the crust of the Venezuela Basin from multichannel reflection data: 8th Caribbean Geol. Conf. Abstr. p. 96-97.

Ladd, John W, J. Lamar Worzel and Joel S. Watkins, 1977, Multifold Seismics reflection records from the northern Venezuela Basin and the north slope of the Muertos Trench: in Talwani and Pitman, editors, Island Arcs, Deep Sea Trenches and Back-Arc Basins: American Geophysical Union, Maurice Ewing series 1, p. 41-56.

Lewis, J.F, 1980, Resume of the Geology of Hispaniola; in Field Guide, 9th Carib. Geol. Conf. Santo Domingo, Dominican Republic. p. 5-31.

Llinas Romeo, 1972, Geologia del Area Polo Duvergé, Cuenca de Enriquillo: CODIA Publicación Sto. Do., Part 1 no. 31 p. 55-65, Part II no. 32 p. 40-53.

Ludwig, W.I., R.E. Houtz & J.J. Ewig, 1975, Profiler-Sonobuoy measurements in Columbia and Venezuela Basins, Caribbean Sea: Amer. Assoc. Petrol. Geol. Bull. v. 59:115-123.

Malfait, B.I. and M.G. Dinkelman, 1972, Circum-Caribbean Tectonic and Igneous Activity and the evolution of the Caribbean Plate: Geol. Soc. America Bulletin, v. 83, p. 251-272.

Matthews, J.E. & T.L. Holcombe, 1976, Regional Geological/Geophysical study of the Caribbean Sea (Navy ocean area NA-9) Geophysical maps of the eastern Caribbean: Naval Ocean. Off. Ref. Publ. RP3 (Dept. Navy, Washington, D.C.).

Maurrasse F., 1973, Sedimentary structures of Caribbean Leg 15 Sediments: in Edgar, N.T., et al., 1973: Initial Reports of the Deep Sea Drilling Project, v. 15, U.S. Govt. Printing Office, Washington, D.C., p. 833-845.

Maurrasse, F., 1976, Cretaceous and Tertiary pelagic facies distribution in the Southern Peninsula of Haiti and the adjacent Caribbean Sea: a view at Caribbean paleogeography and palecology: 3rd Latin American geol. Congr. (Mexico) Abstr. p. 48.

Maurrasse, F., 1979, Cenozic Radiolarian Paleobiography: Implications concerning Plate Tectonics and Climatic Cycles: Palaeogeogr., Palaeoclimat., Paleoecology, v. 26, p. 253-289.

Maurrasse, F. J-M.R., 1982a, New data on the stratigraphy of the Southern Peninsula of Haiti; in F. Maurrasse, editor, Transactions du 1erColloque sur la Géologie d'Haïti, Port-au-Prince, 27-29 Mars 1980, p. 184-198.

Maurrasse, F. J-M.R, 1982b, Les Marges continentales d'Haïti; in F. Maurrasse, editor, Transactions du 1erColloque sur la Géologie d'Haiti, Port-au-Prince, 27-29 Mars 1980 p. 200-206.

Maurrasse, F. J-M.R, 1982c, Relations between the geologic setting of Hispaniola and the origin and evolution of the Caribbean; in F. Maurrasse, editor, Transactions du 1erColloque sur la Géologie d'Haïti, Port-au-Prince, 27-29 Mars 1980, p. 246-264.

Maurrasse F., U. Sayeed, G. Georges, F. Pierre-Louis & J.G. Rigaud, 1977, Ophiolite complex of the Southern Peninsula of Haiti: a view at the Caribbean Crust: 8th Caribbean geol. Conf. Abstr. p. 115-116.

Maurrasse F., Husler, J., G. Georges, Schmitt, R and Damond, P., 1979a, Upraised Caribbean Sea Floor below acoustic reflector B" at the Southern Peninsula of Haiti: Geologie en Mijnbouw, v. 8, no. 1, p. 71-83.

Maurrasse F., Pierre Louis F., Rigaud J.G., 1979b, Upper Cretaceous to lower Paleocene Pelagic calcareous deposits in the southern Peninsula of Haiti: their bearing on the problem of the Cretaceous-tertiary boundary 4th Latin-American Geol. Congress, Trinidad, p. 65.

Maurrasse F., P. Crews and R. Visconti, 1980a, Radiolarian biostratigraphy and paleoecology of the Eastern Part of the Southern Peninsula of Haiti: Amer. Assoc. Petroleum Geologists Bulletin, v. 64, no. 5, p. 747.

Maurrasse, F., Pierre-Louis, F. and Rigaud J. G., 1980b, Cenozoic pelagic sequences in the Southern Peninsula of Hispaniola: their implications concerning the tectonics of the Beata Ridge: 9th Caribbean Geological Conference, Sto. Domingo, Eominican Republic., p. 48.

Maurrasse, F. J-M.R. and F. Pierre-Louis, 1982 a, Relations entre les grandes zones de faille de la région Sud d'Haïti et la production du sable dit de "Laboule"; in F. Maurrasse, editor, Transactions du 1$^{\underline{er}}$ Colloque sur la Géologie d'Haïti, Port-au-Prince, 27-29 Mars 1980, p. 126-133.

Maurrasse, F. J-M.R., F. Pierre-Louis and J-G. Rigaud, 1982b, Cenozoic facies distribution in the Southern Peninsula of Haïti and the Barahona Peninsula, Dominican Republic: in Transactions 9th Caribbean Geological Conf. Santo Domingo, Dominican Republic, p 161-174.

Mitchell, R.C., 1953, New data regarding the diorite rocks of the West Indies: Geol. Mijnbouw N.S. v. 15; p. 285-295.

Molnar, P. & L. Sykes, 1969, Tectonics of the Caribbean and Middle America regions from focal mechanisms and seismicity: Geol. Soc. Amer. Bull., v. 80, p. 1639-1684.

Molnar, P. and L.R. Sykes, 1971, Plate tectonics in the Hispaniola area: discussion: Geol. Soc. America Bull., v. 82, p. 1123-1126.

Moody, J.D., and M.J. Hill, 1956, Wrench-fault tectonics: Geol. Soc. America Bull., v. 67, p. 1207-1246.

Nicolini, Ph., 1977, Porphyres Cuprifères du Nord-Quest d'Haïti: Thèse de 3ème Cycle, Université de Paris 6, France, 208 p.

Officer, C.B., J.I. Ewing, J.F. Hennion, D.G. Harkrider and D.E. Miller, 1959, Geophysical investigations in the eastern Caribbean: summary of 1955 and 1956 Cruise, chap. 2: Physics and chemistry of the earth, v. 3, p. 17-109; Pergamon Press, N.Y.

Pierre, M.G., 1982, Les Roches cristallines d'Haïti: synthese des trauaux de pétrographie et repérage des indices de minéralisation; in F. Maurrasse, editor, Transactions du 1$^{\underline{er}}$ Colloque sur la Géologie d'Haïti, Port-au-Prince, 27-29 Mars 1980, p. 216-234.

Reeside, J.B., Jr., 1947, Upper Cretaceous ammonites from Haiti: U.S. Geol. Surv. Prof. Paper 214A:1-11.

Rigaud, J-G, and F.Pierre-Louis, 1982, Potentiel Petrolier d'Haïti, in F. Maurrasse, editor, Transactions du 1$^{\underline{er}}$ Colloque sur la Géologie d'Haïti, Port-au-Prince, 27-29 Mars 1980, p. 13-23.

Roemer, L., W. Bryant and D. Fahlquist, 1976, A geophysical investigation of the Beata Ridge: in M.R. Causse (ed), Trans. 7th Caribbean Geol. Conf., p. 115-125.

Russell, N., M. Seaward, J. Rivera, K. McCurdey and S.E. Kesler, 1980, The geology of the Pueblo Viejo gold-silver oxide ore body, Dominican Republic: Abs. 9th Carib. Geol. Conf. Santo Domingo, Dominican Republic, p. 64-65.

Sayeed, U., F. Maurrasse, K. Keil, J. Husler and R.A. Schmitt, 1978, Geochemistry and petrology of some mafic rock from Dumisseau, Southern Haiti: EOS, Transactions, American Geophys Union, vol. 59, no. 4, p. 403.

Scherer, J., 1912, Les grands tremblements de terre de l'lle d'Haïti: Observatoire météorologique du Séminaire-Collège St. Martial, Bulletin semestriel, juillet-déc., p. 153-162.

Schneidermann, Nahum, 1973, Pelagic limestone in the Central Caribbean: in Edgar, N.T., et. al., Initial Reports of the Deep Sea Drilling Project, vol. 15, p. 773-793. (U.S. Government Printing Office, Washington, D.C.).

Schubert, C., 1980, Edades 230-Th/234-U de las terrazas marinas pleistocenas de la costa suroriental de la Republica Dominicana: Abs. 9th Carib. Geol. Conf., Santo Domingo, Dominican Republic, p. 66-67.
Stoffa, P.L., A. Mauffret, M. Truchan and P. Buhl, 1981, Sub-B" layering in the Southern Caribbean: The aruba gap and Venezuela basin: Earth Planet. Sci. Letters, v. 53, p. 131-146.
Sykes, L.R. and M. Ewing, 1965, The seismicity of the Caribbean Region: Jour. of Geophys. Research, v. 70, no. 20, p. 5065-5704.
Tippenhauer, L.G., 1893, Die Insel Haiti; 693 p. 21 pls., 23 figs., Leipsig, Germany.
Tippenhauer, L.G. 1901a, Beitrage zur Geologie Haitis: V., Das La Selle-Gebirge, die Cul-de-Sac-Ebene, und das Salzseengebiet: Petermanns Mitt. v. 47:169-178 pls 13-14.
Tippenhauer, L.G., 1901b, Beitrage zur Geologie Haïtis. IV: Das Lignitlager von Maissade: Petermanns Mitteilunger, v. 47, p. 121-127.
Tippenhauer, L.G., 1909, Neuer Beitrag zur Topagraphie, Bevölkerungskunde und Geologie Haïtis: Petermanns Geographische Mitteilunger, v. 55. p. 49-57.
Truan y Luard, A et Witt, O.N., 1898, Die Diatomaceen das Polycystinenkreide von Jérémie in Hayti, Westindien, 24 p, 7 pls, Berlin, Germany.
Vail, P.R., R.M. Mitchum, and S. Thompson, 1977, Seismic Stratigraphy and global changes of sea level, Part 4: Global cycles of relative changes of sea level; in C. Payton, editor, seismic stratigraphy-applications to hydrocarbon exploration: Am. Assoc. Petrol. Geol., Memoir 26, p. 83-97.
Van den Bold, W.A., 1974, "Neogene of Central Haiti", Am. Assoc. Petrol. Geologists, Bull., vol. 58, p. 533-539.
Van den Bold, W.A., 1981, Distribution of Ostracoda in the Neogene of Central Haïti: Bull. Am. Paleontology, vol 79, No. 312, 136 p.
Vaughan, T.W., C Wythe Cooke, Condit D.D., Ross, C.P., Woodring, W.P. and Calkins, F.C., 1921, A Geological Reconnaissance of the Dominican Republic: Dominican Republic Geological Survey Mem., 288 p, 23 pls, Washington, D.C.
Vespucci, P., 1980, Preliminary account of the petrology of the Late Cenozoic volcanic province of Hispaniola: Abs. 9th Carib. Geol. Conf., Santo Domingo, Dominican Republic, p. 76.
Waggoner, D. G., 1978, Sr and Nd-isotope study of the Caribbean basalts belongings to the B" events: Trans. Amer. Geophys. Union, v. 59 no. 4, p. 404.
Watkins, J. and Th. Cavanaugh, 1976, Implications of magnetic anomalies in the Venezuela Basin: in R. Causse (ed), Trans. 7th Caribbean Geol. Conf. p. 127-138.
Westercamp, D., 1980, Diversity, structural control and orgin of recent volcanic rocks in the Lesser Antilles: Abs. 9th Carib. Geol. Conf., Santo Domingo, Dominican Republic, p. 78-79.
Woodring, W.P., 1922a, Middle Eocene Foraminifera of the genus Dictyoconus in the Republic of Haiti: Washington Acad. Sci, Jour, vol. 12, p. 244-247.
Woodring, W.P., 1922b, Stratigraphy, structure, and possible oil resources of the Miocene rocks of the Central Plain: Republic of Haïti, Department of Public Works-Geological Survey of the Republic of Haïti. 19 p. + 1 map.
Woodring, W.P., J.S. Brown et W.S. Burbank, 1924, Géologie de la République d'Haïti, Dept. des Travaux Publics, Port-au-Prince, 710 p. English version: Lord Baltimore Press, Baltimore 631 p.